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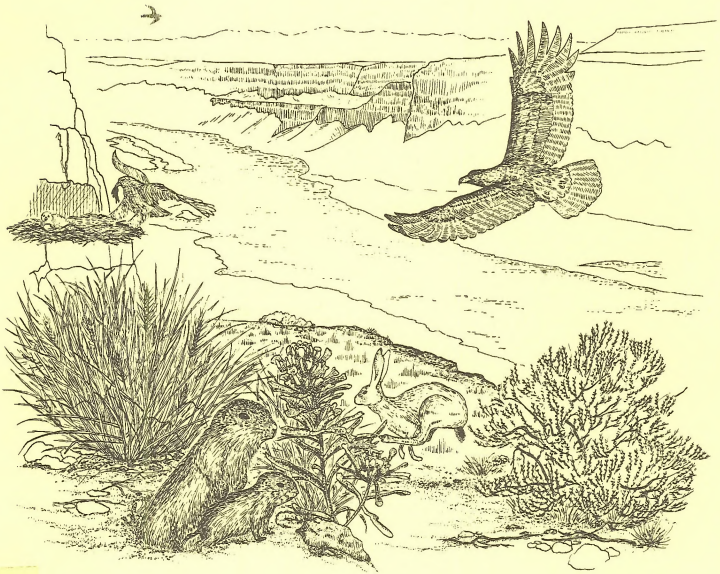

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SNAKE RIVER BIRDS OF PREY NATIONAL CONSERVATION AREA RESEARCH AND MONITORING ANNUAL REPORT 1993

Karen Steenhof
Editor

NOT FOR PUBLICATION

The data presented herein are preliminary and may be inconclusive. Permission to publish or cite any of these materials is therefore withheld pending specific authorization of the Research Leader of the Raptor Research and Technical Assistance Center, NBS, and the specific Principal Investigator.

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PREFACE

This report summarizes research and monitoring activities in the Snake River Birds of Prey Area (SRBOPA) during calendar year 1993. As in previous years the main research effort in the SRBOPA was the BLM/IDARNG Research Project.

National Conservation Area

The SRBOPA was established as a National Conservation Area by Congress in August 1993. This Act provides permanent protection and establishes a management mandate for the area. The Act requires final revision of the SRBOPA Management Plan by January 1996.

RRTAC Activities

A significant event in the Raptor Research and Technical Assistance Center (RRTAC) was the transfer of RRTAC to the U.S. National Biological Survey (NBS), the newly created research bureau within the Department of the Interior. Interior Secretary Bruce Babbit formed this bureau by consolidating research entities from the agencies within the Department. Although the transfer occurred in November 1993, there were no physical changes to RRTAC. As in 1993, RRTAC's main effort, in the short term, is conducting the cooperative BLM/IDARNG Research Project and coordinating other research and monitoring in the SRBOPA. In 1993 RRTAC also conducted numerous technical assistance actions, primarily requests from the RRTAC literature systems.

BLM/IDARNG Research Project

Field Studies: This was the third year of intensive field work for the 5 component studies of this 6-year research project (Table 1). Studies continued at full intensity with more than 75 people in the field. Results of these efforts are presented in the first half of the progress reports of this volume.

Project Integration: Principal accomplishments were similar to 1992 Integration effort. In addition to a Project Integration Workshop, an Integration Team Meeting and a Mid-Project Review were held in March 1993. The latter consisted of the Project Management Oversight Group (MOG) and management personnel from BLM and IDARNG. A significant integration accomplishment was completion of the vegetation map for the Integration Study Area from satellite imagery. Study plans for 1994 were completed and will appear as addenda to the original study plans in the 15 January 1991 Research Plan for the Project. A report of the integration effort is presented in the first half of this volume.

Other Research and Monitoring in the SRBOPA

Considerable work, other than the BLM/IDARNG Project, including long-term monitoring, continued in the SRBOPA by RRTAC, BLM staff, and cooperators. Cooperators consisted of personnel from other agencies, universities, and private industry, as well as private individuals. These investigations are reported in the second half of the progress reports of this volume.

Technology Transfer

Although the main thrust for 1993 was conducting the BLM/IDARNG Research Project and continuation of cooperative research projects, work still continued on Technology Transfer. Four scientific papers were published and/or accepted for publication, and 2 BLM reports were published in 1993, and RRTAC staff and associates made 30 technical presentations at various meetings and workshops.

Table 1. Component Studies of the BLM/IDARNG Research Project

Study 1.	*Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas.* Tom J. Cade, Christine Watson, and Eric Atkenson, Principal Investigators. Raptor Research Center, Boise State University.
Study 2.	Raptor Habitat Use and Foraging Behavior. John Marzluff, Principal Investigator. Greenfalk Consultants.
Study 3.	Raptor Nesting Densities and Reproductive Success. Michael N. Kochert, Robert N. Lehman, and Karen Steenhof, Principal Investigators. Raptor Research and Technical Assistance Center, BLM.*
Study 4.	Townsend's Ground Squirrel Abundance, Productivity, and Habitat Relationships. Beatrice Van Horne, Principal Investigator. Colorado State University.
Study 5.	Vegetation Classification/Description and the Ability of Soils/Vegetation to Support Ground Squirrel and Jackrabbit Populations. Steven T. Knick and Steven Watts, Principal Investigators. Raptor Research and Technical Assistance Center, BLM.*
Study Integration	John Rotenberry, Integration Leader. University of California, Riverside.

Technical Advisory and Review Panel

Michael Collopy, NBS Cooperative Research Center,
Corvallis, Oregon;

Brian Maurer, Brigham Young University,
Provo, Utah;

Graham Smith, U.S. Fish and Wildlife Service
Office of Migratory Bird Management,
Patuxent, Maryland; and

Jay Anderson, Idaho State University,
Pocatello, Idaho

*Presently U.S. National Biological Survey

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COOPERATING AGENCIES AND INSTITUTIONS

Albertson's College of Idaho
Boise State University, Raptor Research Center
Colorado State University
Greenfalk Consultants
Idaho Army National Guard
Idaho Department of Fish and Game
Idaho Department of Transportation
Idaho Department of Water Resources
Idaho Power Company
Idaho State University
PaciCorp
Peregrine Fund; World Center for Birds of Prey
University of Idaho
University of New Mexico
U.S. Army Chemical Engineering and Research Center
U.S. Army Corps of Engineers, CERL
U.S. Fish and Wildlife Service
Bird Banding Laboratory*
Idaho State Office
Office of Migratory Bird Management
Patuxent Wildlife Research Center*
U.S. Forest Service Intermountain Research Station
U.S. National Biological Survey
Utah State University
Weber State University

*Presently with U.S. National Biological Survey

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PART I

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*Published and/or accepted for publication in 1993. Reprints of most of these articles are available from the Raptor Research and Technical Assistance Center, National Biological Survey, 3948 Development Avenue, Boise, ID 83705.

1993 RRTAC/SRBOPA TECHNICAL PRESENTATIONS

6 Jan 93 **Fuller, M.R.** Telemetry specialist's perspective. Conference on Radio Telemetry in Support of Avian/Pesticide Field Studies. Soc. Environ. Toxicology and Chemistry, Asilomar, California.

10 Feb 93 **Steenhof, K.** Boise's urban bald eagles. Noon Seminar Series. Boise State University Biology Department, Boise, Idaho.

23 Feb 93 **Kochert, M.N.** Raptor ecology and investigations in the proposed Snake River Birds of Prey NCA. Invited lecture. Morrison Knudsen Nature Center, Boise, Idaho.

25 Mar 93 **Knick, S.T.**, and J.T. Rotenberry. Bird communities and spatial heterogeneity of landscapes in southwestern Idaho. Annual Meeting, Idaho Chapter, The Wildlife Society, Boise, Idaho.

25 Mar 93 Kochert, M.N., and **K. Steenhof**. Effect of prey and weather on golden eagle reproductive rates. Annual Meeting, Idaho Chapter, The Wildlife Society, Boise, Idaho.

26 Mar 93 **Knick, S.T.**, J.T. Rotenberry, and T. Zarriello. Habitat delineation from Landsat thematic mapper satellite imagery in southwestern Idaho. Annual Meeting, Idaho Chapter, The Wildlife Society, Boise, Idaho.

26 Mar 93 **Pellant, M.** Advancements in the rehabilitation of burned rangelands in southern Idaho. Annual Meeting, Idaho Chapter, The Wildlife Society, Boise, Idaho.

27 Mar 93 **Ulmschneider, H.** Wintering and nesting site fidelity of long-eared owls in the Snake River Birds of Prey Area. Annual Meeting, Idaho Chapter, The Wildlife Society, Boise, Idaho.

31 Mar 93 **Steenhof, K.** Bald Eagle recovery. Guest lecture for Boise State University Biology Department Graduate Seminar on Endangered Species, Boise, Idaho.

16 Apr 93 **Wilber, P.G.**, B. Hanelt, and D.W. Duszynski. Temporal changes in the prevalence of eimerians in a free-living population of Townsend's ground squirrels (*Spermophilus townsendii*). Southwestern Association of Parasitologists' Meeting. Lake Texoma, Oklahoma.

27 Apr 93 **Rains, C.R.** Breeding biology of the northern saw-whet owl (*Aegolius acadicus*) in southwestern Idaho. Golden Eagle Audubon Society meeting. Boise, Idaho.

20 Jun 93 **Corn, J.G.**, B.A. Wunder, and B. Van Horne. Fatty acid composition of adipose tissue in Townsend's ground squirrels. American Society of Mammalogists Meeting, Bellingham, Washington.

20 Jun 93 Schooley, R.L., **B. Van Horne**, K.P. Burnham, P.B. Sharpe, G.S. Olson, J.G. Corn, and P.G. Wilber. Habitat relationships of the Townsend's ground squirrel, *Spermophilus townsendii*, in a food-limited system. American Society of Mammalogists Meeting, Bellingham, Washington.

21 Jun 93 **Olson, G.S.**, and K.P. Burnham. Modeling survival rates of Townsend's ground squirrels. American Society of Mammalogists Meeting, Bellingham, Washington.

21 Jun 93 **Van Horne, B.**, and R.L. Schooley. Effects of drought on populations of **Spermophilus townsendii** in the Snake River Birds of Prey Area, Idaho. American Society of Mammalogists Meeting, Bellingham, Washington.

21 Jun 93 **Burnham, K.P.** Estimation of boundary strip width for small-mammal livetrap grids. American Society of Mammalogists Meeting, Bellingham, Washington.

21 Jun 93 **Wilber, P.G.**, and D.W. Duszynski. Ulceration and parasitism in Townsend's ground squirrels (*Spermophilus townsendii*): drought and density induced? American Society of Mammalogists Meeting, Bellingham, Washington.

23 Jun 93 **Sharpe, P.** Behavior of Townsend's ground squirrels in the Snake River Birds of Prey Area, Idaho. American Society of Mammalogists Meeting, Bellingham, Washington.

3 Aug 93 **Van Horne, B.** Habitat relationships of the Townsend's ground squirrel, *Spermophilus townsendii*, in a food-limited system. Poster presentation. Ecological Society of America, Madison, Wisconsin.

15 Sep 93 **Kochert, M.N., and R.R. Olendorff.** Creating raptor benefits out of power line problems. Symposium on Raptor-Human Interactions. University of Kent, Canterbury, England.

1 Nov 93 **Wilber, P.G.,** B. Hanelt, and D.W. Duszynski. Factors influencing the eimerian community in a free-living population of Townsend's ground squirrels (*Spermophilus townsendii*). American Society of Parasitologists Meeting. Atlanta, Georgia.

27 Sept 93 **Kochert, M.N.** Ecological research in the SRBOPA: a multi-disciplined team approach. Invited seminar. Royal Society for Protection of Birds. Edinburgh, Scotland.

1 Nov 93 **Kochert, M.N.** Raptor-prey ecology in the SRBOPA. Seminar. Purdue University, West Lafayette, Indiana.

4 Nov 93 **Carpenter, G.P.** Effects of food availability on breeding American kestrels in southwestern Idaho. Raptor Research Foundation Annual Meeting, Charlotte, North Carolina.

4 Nov 93 **S. Brodeur,** D.M. Bird, R. Decarie, M.Fuller, and S. Klugman. Year-round movements of satellite-tracked golden eagles breeding in Quebec. Raptor Research Foundation Annual Meeting, Charlotte, North Carolina.

5 Nov 93 **Rains, C.** Occupancy and productivity of northern saw-whet owls using nest boxes in southwestern Idaho. Raptor Research Foundation Annual Meeting, Charlotte, North Carolina.

5 Nov 93 **Vekasy, M.,** J. Marzluff, M. McFadzen, B. Lehman, K. Steenhof, and M. Kochert. Effects of radio transmitters on productivity of prairie falcons and golden eagles. Raptor Research Foundation Annual Meeting, Charlotte, North Carolina.

5 Nov 93 **Garcelon, D.,** E.G. Lobkov, M.J. McGrady, M.R. Fuller, P. Schempf, E.R. Potapov, and H. Nakagawa. Preliminary report on the status of Steller's Sea Eagles in Russia. Raptor Research Foundation Annual Meeting, Charlotte, North Carolina.

5 Nov 93 **Kimsey, B.A.,** and J.M. Marzluff. Effects of triangulation error on home range estimates of prairie falcons (*Falco mexicanus*). Raptor Research Foundation Annual Meeting, Charlotte, North Carolina.

5 Nov 93 **Marzluff, J.M.** Foraging relationships between corvids and golden eagles: mutual parasitism? Raptor Research Foundation Annual Meeting, Charlotte, North Carolina.

17 Nov 93 **Marzluff, J.M.** Ravens: the art of socializing. Invited lecture. Morrison Knudsen Nature Center, Boise, Idaho.

18 Nov 93 **Rains, C.R.** Biology of the northern saw-whet owl, *Aegolius acadicus*. Invited lecture. Morrison Knudsen Nature Center, Boise, Idaho.

PART II

PROGRESS REPORTS

Raptor Abundance and Reproductive Success in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*In 1993, the number of prairie falcon (**Falco mexicanus**) pairs (187) in the Snake River Birds of Prey Area (SRBOPA) was higher than in 1978, 1990, and 1991, but slightly lower than numbers observed in 1976, 1977, and 1992. Numbers of pairs in 8 randomly selected 10-km stretches were below the long-term average. Occupancy of historical prairie falcon nesting areas was highest in canyon stretches west of the Orchard Training Area (OTA) "shadow," and lowest east of the "shadow." Nesting success inside the OTA shadow was significantly lower than success west and east of the shadow. Both the number of young prairie falcons produced per nesting attempt in the SRBOPA (2.11) and the number of young per pair (1.82) were below the long-term average. Golden eagle (**Aquila chrysaetos**) numbers in the SRBOPA were slightly lower than in 1992 but the same as in 1991. Number of young eagles fledged per pair (1.23) was higher than the previous 10 years. For the second time since 1986, golden eagle reproduction (young per pair) in the SRBOPA was nearly the same as in the Comparison Area. Twenty-five of 61 historically occupied ferruginous hawk (**Buteo regalis**) nesting areas were occupied, including 8 in the Snake River Canyon, 13 on the benchlands, and 4 outside the Integration Study Area (ISA). One new ferruginous hawk nesting area was found. We found 106 occupied raptor nesting areas on the ISA benchlands, 12 more than in 1992. These included 14 ferruginous hawk, 10 northern harrier (**Circus cyaneus**), 71 burrowing owl (**Speotyto cunicularia**), and 11 short-eared owl (**Asio flammeus**) pairs. Relative abundance of benchland nesters inside and outside the OTA was similar. Nesting success of ferruginous hawks, northern harriers, and short-eared owls inside and outside the OTA could not be evaluated because of low sample sizes. Nesting success for burrowing owls did not differ significantly inside and outside the OTA. Habitat analyses indicated that hills, artificial perch and nest structures, agriculture, soil depth, percent vegetative cover, percent shrub cover, and mean shrub height may be related to nest site selection on the bench. Distances of burrowing owl nesting areas in the OTA to roads and firing ranges were not significantly different than those of random points. Distances of bivouac sites, tank maneuver areas, tank tracking areas, and firing ranges to successful and unsuccessful burrowing owl nests did not differ significantly.*

OBJECTIVES

1. Assess 1993 prairie falcon abundance and long-term population trends in the Snake River Birds of Prey Area (SRBOPA) and compare 1993 falcon nesting densities inside and outside the Orchard Training Area (OTA) shadow.

2. Assess prairie falcon reproduction at preselected nesting areas and compare estimates of productivity to long-term trends in the SRBOPA.

3. Compare prairie falcon nesting success, productivity, and fledging weights inside and outside the OTA Shadow.

4. Compare 1993 golden eagle abundance and productivity in the SRBOPA and Comparison Area.

5. Assess the relative abundance and reproductive success of benchland-nesting raptors inside and outside the OTA.

6. Compare habitat and land use characteristics of occupied benchland nesting areas to randomly selected unoccupied areas on the bench.

7. Assess ferruginous hawk occupancy and nesting success at historical nesting areas.

8. Report recoveries of banded raptors and assess preliminary information on nest site fidelity and breeding dispersal.

9. Assess the relationship between wildfires and golden eagle and ferruginous hawk occupancy and reproductive success.

INTRODUCTION

Study 3's main objective is to determine if nesting densities and reproduction of the major raptor species in the SRBOPA have changed over time and if any such changes can be correlated with military use and fire occurrence. In addition, a long-term approach for monitoring raptor nesting populations will be recommended based on this research.

The 1993 field season was the fourth year of the study. Field work emphasized Tasks 1, 2, 3, and 4 of the Study 3 Plan (Kochert et al. 1991). For Task 1 (the bench survey), we conducted a quadrat survey, similar to that used in 1990 and 1992, but modified the size and number of quadrats and the sampling technique. In 1991, line transects and variable circular plots were sampled. General approaches for Tasks 2 and 3 (comparison of past and present raptor nesting densities and OTA effects) did not change or changed only slightly in 1993. Density and reproductive data were collected on golden eagles and ferruginous hawks for Task 4 (burn effects), and for the first time we analyzed golden eagle data from historical burn maps. As in 1992, the site fidelity work (Task 5) was scaled back to include only opportunistic encounters with banded prairie falcons. During habitat assessments on the bench, we used the same habitat variables used in 1992, but protocols for obtaining habitat data changed slightly in 1993.

METHODS

Prairie Falcon Abundance and Reproduction

Abundance.—In 1993, all stretches of the Snake River Canyon and major side canyons within the SRBOPA (Hammett to Walters Ferry) were surveyed for prairie falcon nesting activity 3 times: once between 5 March and 8 April; once between 30 April and 27 May; and once between 5 June and 21 June. As in past years, some buttes and portions of side canyons (Walters Butte, Rock Cabin Spring, Little Hole, and Rattlesnake Spring nesting areas) were excluded from the survey area.

Each month, observers surveyed standardized stretches of the canyon from observation points, spaced at approximately 1-km intervals. Some side draws consisting of small or broken cliffs were surveyed by walking. We avoided surveys from fixed observation points when our presence would have disturbed other target species of nesting raptors (e.g., golden eagles or ferruginous hawks). Most observation points were on the canyon floor so observers faced the potential nesting cliffs. Observations were made from the canyon rim along a few stretches where the view was obscured from below. Each observation point was surveyed for 2 hrs during each monthly sur-

vey. When the survey stretch was less than 1 km, survey time was proportionately less. Only 1 side of the canyon was surveyed from each observation point except where the canyon was very constricted.

Observers recorded nesting activity of all raptors and ravens in field journals and on 1:24,000-scale U.S.G.S. topographic maps. To improve accuracy, we also plotted nests on black and white 1:24,000-scale aerial photographs. Observations of birds wearing colored leg bands, U.S. Fish and Wildlife Service leg bands, or other markers were also recorded. A nesting area was considered occupied if territorial defense, courtship, or other reproductive activity was observed (U.S. Dep. Inter. 1992).

Results were analyzed for the entire SRBOPA and for 10-km stretches of the canyon delineated in U.S. Dep. Inter. (1979). Data were compared with years when surveys of the entire area were complete (1976, 1977, 1978, 1990, 1991, and 1992) and for certain 10-km stretches surveyed between 1976 and 1992. Nesting densities in each 10-km unit were analyzed in relation to the amount of available cliff area, as calculated by Bentley and Hardyman (1978) and presented in U.S. Dep. Inter. (1979).

As in 1992, the OTA "Shadow" (previously defined as 10-km Units 7, 8, and 9) was extended west to include 10-km unit 6, based on 1991 radio-telemetry results (Marzluff et al. 1991). Densities in the OTA Shadow (Units 6, 7, 8, and 9) were compared with stretches southwest and southeast of the OTA.

Reproduction.—Prairie falcon nesting success and productivity in the SRBOPA were assessed for 2 treatment groups in 1993. Study 2 assessed reproduction at nesting areas where they radioed adults in 1993, and Study 3 assessed reproduction at a randomly selected sample of "control" nesting areas; i.e., those not radioed in 1993. Randomly selected control areas where ≥1 adult was wearing a radio from a previous year were excluded from analyses of radio effects.

Before the nesting season, all historical nesting areas in the Integration Study Area (ISA) were stratified as east, west, or inside the OTA shadow, and nesting areas were randomly assigned to Study 2 and Study 3. The order of random selection determined which nesting areas would be studied and which would be back-up sites. As in 1991 and 1992, the target "control" sample size (based on power tests; Kochert et al. 1991) was 51 "control" nesting areas. In 1993, target sample sizes for the 3 strata were the same as in 1992 but differed slightly from the 1991 samples (due to the OTA configuration change described above). In 1993, target sample sizes were 12 nesting areas from 10-km units west of the OTA Shadow, 23 from units inside the OTA Shadow, and 16 from units east of the OTA Shadow. As in 1992, 10 nesting areas were also selected east of the ISA boundary to monitor reproductive success throughout the SRBOPA. Nesting areas east of the ISA boundary were not used in the analysis of OTA effects.

We began monitoring selected "control" nesting areas in early March (prior to incubation), and continued observations up to the time of fledging. All selected nesting areas were checked during each of the 3 density surveys. If occupancy was not determined during the March survey, replacement nesting areas were selected from the list of backups in the original random order. We continued observations at the replaced nesting areas until we were certain they were unoccupied, usually after 6-8 hrs of observation.

Between early April and late May, nesting areas were observed from remote observation points to identify probable nesting scrapes. Each observation bout continued for up to 4 hrs. Criteria for confirming scrape locations and thereby identifying probable breeding attempts included: observation of eggs in a scrape or nest; an adult observed in incubating posture; or observations of an adult falcon entering a scrape and remaining within the scrape for 1 hr or more. If scrape locations could not be identified during scheduled observation bouts, we climbed to locate scrapes. We continued observations at nesting areas where scrapes could not be identified to determine if nonbreeding pairs were present.

Nesting attempts were considered successful if ≥1 young reached 30 days of age (Steenhof 1987). Nestlings were aged at most nests by remote observations late in the brood-rearing period using a photographic aging key (Moritsch 1983). Some nests were climbed to age young. Nest climbs to count fledging-aged young occurred when young were 30-35 days old. During nest climbs, young were weighed, examined for condition, and banded with a USFWS band on the right leg and

a red anodized aluminum band with a unique alphanumeric code on the left leg. We also measured foot pad length, tarsal width, and length of the seventh primary. To control for observer bias, measurements were taken by only 3 people. Because of time and logistical constraints, we did not exchange personnel with Study 2 when broods were measured in 1993 (in previous years, this was done to control for observer bias). Weights were adjusted on all birds whose crops were more than 25% full by subtracting estimated crop weights (BLM, unpubl. data). Birds with foot pads >86 mm were considered to be females, and those with foot pads <86 mm were called males.

To compare productivity among years, we used only 1993 "control" nesting areas and excluded nesting areas from previous years where experimental disturbances, nest site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment occurred. This ensured that results were not biased by researcher manipulations. Analyses of percent of pairs successful were based on pairs selected for study prior to each nesting season. To assess the percent of nesting attempts successful, only those breeding attempts confirmed during incubation and for which outcome was known were included in the analysis. Number of young fledged per successful attempt was based on all control pairs for which complete fledge counts were obtained. Number fledged per pair and per attempt were estimated as the products of percent success and number fledged per successful attempt.

Golden Eagle Abundance and Reproduction

In 1993, 39 traditional golden eagle nesting areas in the SRBOPA and 23 nesting areas in the Comparison Area (see Kochert et al. 1991) were preselected for observation. All 62 nesting areas were surveyed by helicopter or from the ground in conjunction with other raptor surveys. Helicopter surveys were conducted from a Bell 206 Jet Ranger on 15 March, 1 June, and 29 June. The purpose of the first survey was to determine if nesting areas were occupied and if eggs had been laid. Nesting areas with breeding pairs were re-checked during the second and third flights to assess productivity. In addition, golden eagle nesting areas on the Pacific Power and Light (PP&L) transmission line and selected areas in the canyon and Comparison Areas were surveyed from a helicopter on 28 April, in conjunction with a ferruginous hawk survey. Helicopter surveys were conducted along the Snake River from Givens Hot Springs east to Glenns Ferry, and along the PP&L transmission line from Miles 45 to 127 in March, Miles 50 to 115 in June, and Miles 52 to 119 in April. Selected nesting areas in the canyon and along the PP&L transmission line where nesting success had not been determined during previous surveys were checked during the 28 April and 29 June flights. Helicopters were flown at speeds of 70-95 km/hr, and we hovered approximately 10 m from nests for 5-25 sec to view nest contents. No attempt was made to flush incubating birds or count eggs.

Nesting areas where occupancy or breeding status could not be ascertained during helicopter flights were surveyed from the ground. Ground surveys in 1993 were conducted in conjunction with prairie falcon density surveys in the SRBOPA. Some nests in the Comparison Area were surveyed from the ground by Idaho Power Company personnel. Nine golden eagle pairs were used for Study 2's radio telemetry work (Marzluff et al., this volume).

Eagle pairs that showed no evidence of egg-laying after repeated observations were categorized as "nonbreeding." A "breeding attempt" was confirmed if an occupied nesting area contained an incubating adult, eggs, young, or any indication that eggs had been laid (e.g., fresh eggshell fragments in fresh nesting material). A breeding attempt was "successful" if ≥1 young reached 51 days of age (Steenhof 1987). A photographic aging key was used to age young (Hoechlin 1976). Eagle nests checked after young had fledged were considered successful if: (1) a platform decorated this season was worn flat and contained fresh prey remains; (2) fresh fecal matter covered the back and extended over the edge of the nest; and (3) no dead young birds were found within a 50-m radius of the nest.

Percent of pairs breeding in 1993 and earlier years was calculated from preselected pairs (Steenhof and Kochert 1982). Percent of nesting attempts that were successful was based on attempts confirmed during incubation. Nesting areas where researcher manipulations (experimental disturbances, nest-site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment) had occurred were excluded from analyses of percent success.

To assess relationships between wildfire and golden eagle occupancy and reproductive success, we estimated the relative proportion of the area that burned since 1980 in a 2.6-km radius circle around the centroid of each historical golden eagle nesting area in the SRBOPA. The 2.6-km radius circles were overlaid on the Digitized Resource Data Base Map (DRDBM) of composite burns in the SRBOPA since 1980, and the relative proportion of area burned around each nesting area was categorically assessed. Circles with >40% burned were categorized as high burn nesting areas and those with <40% burned were categorized as low burn areas. We also estimated the relative amount of agriculture within the 2.6-km circles in the same manner as burns and categorized relative amounts of agriculture into nesting areas with <20% and >20% agriculture.

Ferruginous Hawk Occupancy and Reproduction

In 1993, we preselected 55 of 81 historically occupied ferruginous hawk nesting areas in the SRBOPA. These were classified as ISA or non-ISA areas. In the ISA, nesting areas were classified as benchland or canyon areas. In 1993, we surveyed all 31 canyon nesting areas, 19 of 36 benchland areas, and 5 of 15 non-ISA areas. On the benchlands and outside the ISA, we visited all nesting areas occupied in 1991 and 1992. We also surveyed 6 historically occupied nesting areas that were not preselected.

Canyon nesting areas were observed during the March, May, and June prairie falcon density surveys. Benchland nesting areas in the ISA were surveyed at least 3 times between 15 March and 13 July (see the Benchland section below). Non-ISA nesting areas were surveyed at least twice. All occupied historical nesting areas were revisited until success was determined. A nesting area was considered occupied if territorial defense, courtship, or other reproductive activity was observed (U.S. Dep. Inter. 1992).

In addition to ground surveys, a helicopter survey was conducted on 28 April. The survey included all nesting areas on the PP&L transmission line within the SRBOPA as well as any occupied nesting areas in the canyon and outside the ISA where breeding status was previously undetermined. Ferruginous hawk nesting areas found for the first time in 1993 were revisited as necessary to determine breeding status and nesting success. To report success rates we used all nesting areas confirmed during incubation (where eggs or an incubating adult was seen) and where fate was known. Nesting attempts were considered successful if ≥1 young reached 31 days. Nestlings were aged using a photographic aging key (Moritsch 1985).

We assessed relationships between ferruginous hawk occupancy and wildfires using methods similar to those described above for golden eagles, but conducted the analysis only for 1992 and used only those nesting areas that occurred in the ISA. This was the only year that surveys were complete for this species since the late 1970's. We also reduced the diameter of the circular sampling area to 1.5 km, and categorized burned areas as those with >50% of the circle burned and unburned areas as those with <50% burned. Percent agriculture at all sites was <5% so agricultural relationships were not analyzed. We used contingency table analysis to compare differences in occupancy between burned and unburned areas.

Nesting of Raptors on the Benchlands

Relative Abundance.—To assess the relative abundance of raptors nesting on the benchlands north of the canyon, we searched randomly selected quadrats inside and outside the OTA to locate occupied nesting areas. In 1992, we surveyed 44 9-km^2 quadrats but missed over 33% of the occupied nesting areas present in the quadrats. In 1993, we reduced quadrat size to 6 km^2 to improve survey coverage. As in 1992, quadrats had a north-south orientation, but north-south boundaries were 2 km long, and east-west boundaries were 3 km. Target species for relative abundance assessments included the ferruginous hawk, northern harrier, burrowing owl, and short-eared owl.

The goal of quadrat surveys was to locate as many nesting areas within the sampling units as possible. In 1992, we imposed no minimum survey period but set a maximum survey period of 8 hrs. To improve coverage of quadrats, in 1993 we set a minimum survey period of 6.hrs and extended the 8-hr restriction to 12 hrs.

To select quadrats, we superimposed a 6-km^2 cell grid on the ISA using the Geographic Information System (GIS). Cells falling on the ISA or OTA boundaries, within 250 m of the canyon

rim, or within the Artillery Impact Area were rejected. We then randomly selected 50 cells as survey quadrats from those remaining on the grid. Quadrat boundaries were drawn on U.S. Geological Survey 1:24,000-scale topographic maps and orthophoto quadrangles. For quadrats outside the OTA, we examined the orthophoto quadrangles and black and white 1:24,000-scale 1987 aerial photographs to assess amounts of agricultural development (irrigated or dry cropland and irrigated pasture) within each quadrat. Those with ≥10% of their surface areas developed were rejected. We selected new quadrats as needed to assure a minimum sample size of 40 quadrats (15 inside the OTA and 25 outside). The extent of agricultural development in each selected quadrat was verified on the ground during the first field survey.

We sampled each quadrat twice during the nesting period. At least 1 survey began at dawn or ended at dusk. The first survey was conducted from 24 March to 20 April, and the second survey 26 April to 4 June. We attempted to complete the first survey before the mean hatching date for the 4 target species combined (14 April), but missed the target date by 6 days, due primarily to weather and access problems. Because nesting areas are more easily detected late in the breeding period when young are present (Steenhof 1987), we scheduled the second quadrat survey 2 weeks later than in 1992. Quadrats were usually surveyed by 1 person, but we sent different observers to each quadrat during the 2 surveys. Follow-up surveys of occupied nesting areas were scheduled according to estimated ages of nestlings, or if age estimates were not available, prior to the earliest known fledging date of each target species.

We did not mark quadrat boundaries in the field; instead, we used maps and compasses and focused on geographic features to remain inside quadrats. We usually drove, and sometimes walked, all roads within each quadrat, pausing occasionally to scan for raptors. We then walked areas within sampling units not visible from roads. We did not follow a particular pattern during walking surveys, but tried to visually scan all areas not covered while driving. To ensure uniform coverage throughout each quadrat, we developed a strategy for searching before each quadrat survey. Observers judged when a quadrat had been adequately surveyed.

During quadrat surveys, we noted the behavior of all raptors observed. A nesting area was considered occupied if territorial defense, courtship, or other reproductive-related activity was observed (see U.S. Dep. Inter. 1992). Evidence for a breeding attempt included the presence of eggs or young or any field sign indicating that eggs were laid (e.g., adults in incubating posture, eggshell fragments in fresh nesting material—U.S. Dep. Inter. 1992). We tried to assess fate at all nesting areas where breeding attempts were confirmed using protocols described below for historical nesting areas.

When we suspected nesting activity within a quadrat, observers immediately conducted a short search to locate the nest. If nests could not be located within 0.5 hr, the survey resumed. We visited these areas later to locate nests. Follow-up visits were scheduled before the mean hatching date for each species. Chronologies of ferruginous hawks, burrowing owls, and northern harriers were based on SRBOPA nesting records; dates for short-eared owls were based on Linner (1980). When nests were found, observers plotted the locations on field maps using aerial photographs and orthophoto quadrangles. To ensure that nests could be found during follow-up surveys, observers flagged a nearby shrub or a stake in shrubless areas no closer than 10 m from a nest, and recorded directions to the nest. When possible, the same observer who found a nest returned for follow-up surveys. Coordinates of nests, or the centroids of nesting areas where nests were not found, were established using the Global Positioning System (GPS) during habitat surveys (described below) in July and August.

To assess differences in relative abundance inside and outside the OTA, we classified quadrats based on whether or not occupied nesting areas (all species pooled) were found. Groups were compared inside and outside the OTA using contingency table analysis.

Historical Nesting Areas.—Of 172 raptor nesting areas on the ISA benchlands known to be occupied at least once in previous years, 142 were visited in 1993. Because time limitations prevented visits to all 172 historical nesting areas, we prioritized surveys of historical nesting areas by the year each was last used. We first checked all nesting areas occupied in 1992, and then all those occupied in 1991. Nesting areas occupied before 1991 were checked as time permitted. We consid-

ered a historical nesting area to be vacant if no signs of occupancy were seen during the egg laying to broodrearing period for each species. Usually this required at least 3 checks during the nesting period and at least 3 hrs of observation. Initial visits at all nesting areas occurred between 22 March and 25 April.

In 1993, we expanded search protocols for historical nesting areas to account for species differences in nesting habits. As in 1992, we first checked each known nest within a historical nesting area during the first visit. In some cases, we also checked other potential nesting substrates visible from historical nests. However, in 1993 search areas consisted of a circular plot centered on the historical nesting area or the centroid of a historical nesting area if ≥1 nest was used. Radii of search areas were 1 km for ferruginous hawk nesting areas, 400 m for short-eared owl and northern harrier nesting areas, and 300 m for burrowing owl nesting areas.

For ferruginous hawks, observers spent roughly 1 to 1.5 hrs on site during each visit. This allowed all rock outcrops and other suitable substrates within a 1-km radius to be checked. On flat, open ground, observers scanned the search area from the centroid.

Visits to burrowing owl nesting areas had no time limit but were not less than 0.5 hr. We visited each nesting area 4-6 times, often during early morning or late evening hours. In addition, we broadcast taped burrowing owl vocalizations when visiting nesting areas to increase detection rates (D. Beig, Boise State University, pers. commun.). We usually broadcast taped calls for 1 min then scanned with binoculars for 5 min to detect owls that may have been attracted by the calls. Broadcast bouts were repeated, usually for at least 0.5 hr.

For short-eared owl and northern harriers, a search on foot within the prescribed search area (400 m) was conducted. Both species flush from their nests only when observers are very close; thus, during each visit we searched all shrub and dead Russian thistle (*Salsola iberica*) stands thoroughly. Most short-eared owl nesting areas were surveyed for more than 3 hrs. Many visits occurred as part of a short-eared owl radiotelemetry project conducted in the SRBOPA in 1993 (see Rivest, this volume).

If nesting attempts were confirmed at historical nesting areas during initial visits, the areas were revisited just before fledging to determine success. We revisited all occupied nesting areas where nesting attempts were not confirmed when first found. Ferruginous hawk breeding attempts were considered successful if ≥1 or more young reached 31 days of age, and burrowing owl breeding attempts were considered successful if ≥1 young reached 28 days of age. We used photographic aging keys (Moritsch 1985, and J. Priest, Humane Society of Santa Clara, California, unpubl. data) to age nestlings of both species. Short-eared owl and northern harrier nesting attempts were considered successful if ≥1 young reached 20 and 24 days, respectively (Clark 1975, Steenhof 1987). We used descriptions of feather development to age nestlings of both species. For northern harriers, nestling ages were based on Bent (1961) and Watson (1977). For short-eared owls, nestling ages were based on Karalus and Eckert (1987) and Johnsgard (1988). Nest visits to confirm success continued through 15 August.

Other Nesting Areas.—To locate nesting areas not recorded previously, we followed up all observations of reproductive-related activity involving any of the 4 target species reported by Study 3 personnel or other study teams. If nesting activity was observed by Study 3 personnel while traveling in the ISA, observers conducted an immediate search of the area for evidence of a nesting attempt. We asked other study teams involved in BLM/IDARNG research to record observations on a standard data form. All nesting areas where breeding was confirmed were revisited later in the nesting season to determine nesting success. Visits were scheduled according to the nesting chronologies of the 4 target species, as cited above for historical nesting areas, using similar protocols.

Assessment of Nesting Success.—To assess reproductive success of nesting raptors on the benchlands, we tried to assess fate at historically occupied nesting areas, nesting areas found during quadrat surveys, and nesting areas found opportunistically by Study 3 and other study teams. We analyzed only those ferruginous hawk, northern harrier, and short-eared owl nesting attempts found during incubation (where adults in incubating position or eggs were observed).

We determined if successful burrowing owl pairs were found during incubation by backdating

from age estimates of young obtained after young had emerged from their burrows, using an incubation period of 30 days (Henny and Blus 1981). In 1992, we suspected that we missed burrowing owl pairs that failed early in the breeding period, thus inflating nesting success. In 1993, we began burrowing owl surveys earlier (26 March) and concentrated our searches of historical nesting areas and quadrats during early morning or late evening hours to improve our sample of nesting areas found early in the breeding period. We also analyzed nesting success only for those pairs found before the median hatch date (6 June) rather than the earliest hatch date, as in 1992, to improve our sample of occupied nests found during incubation.

In 1992, we found nests at only 12 of 24 short-eared owl nesting areas identified. In 1993, we conducted intensive observations at suspected nesting areas at dawn and dusk in an attempt to increase detection rates. We also listened for food-begging calls at night to find dispersed young (D. Holt, Institute for Owl research, pers. commun.).

Habitat Assessments.—Habitat assessments in the ISA had 3 objectives: (1) to identify habitat characteristics associated with nest site selection; (2) to identify habitat characteristics associated with nesting success; and (3) to assess the relative availability of important habitat features inside and outside the OTA.

We used contingency table analyses (G-tests) to assess differences in categorical habitat variables between nests and random points, and between successful and unsuccessful nesting areas. We used t-tests to assess similar differences in continuous habitat variables, and the Wilcoxon Rank Sum test as a nonparametric alternative to the t-test for variables that were not normally distributed. We also assessed habitat differences between nests and random points using stepwise logistic regression. Habitat characteristics at random points inside and outside the OTA were compared using G-tests and t-tests. The SAS statistical package (SAS Statistical Institute 1990) was used for all statistical analyses.

Habitat characteristics were described at 105 occupied nesting areas and 97 random points. Habitat characteristics were not described at 1 burrowing owl nesting area that occurred in a plowed field on private land. Habitat at occupied nesting areas was assessed by Study 3 field crews during a final visit after fledging. These visits occurred between 25 June and 19 August. Habitat at random points was assessed by Study 5 field crews between 24 June and 5 August.

Study 3 field personnel estimated habitat variables ocularly within 50-m and 100-m radii of nests and random points. Variables included number of rock outcrops, vegetative cover classes, presence of hills and buttes (with slopes >15%), presence of agricultural development, artificial perches, artificial nest structures, and roads. We also assessed the presence of agricultural development (defined as any irrigated land, including irrigated pasture) and described vegetative cover types within a 500-m radius of the nest and random point. Slope of hills and buttes was measured with a clinometer or estimated visually. Vegetative cover classes were described as "open" or "closed." Open cover types had low vegetation (e.g., grasses) or lacked vegetative cover within ≥50% of the prescribed radius. Closed cover types had shrubs within ≥50% of the prescribed radius.

Habitat characteristics obtained from the DRDBM included grazing regime type, soil depth, soil development, and landform. Grazing seasons were either spring-fall (north of the drift fence) or winter (south of the drift fence). Soils data were obtained from Ada, Canyon, Elmore, and Owhyee County soil surveys (U.S. Dep. Agric. 1972, 1980, 1991, unpubl.). Soil depth was analyzed for 3 categories: shallow (<51 cm), medium (51-102 cm), and deep (>102 cm). Landform was classed as "basaltic" or "other soil type," and soil development was considered either "strong" or "weak." We also calculated the proportion of each military regime within a 1-km radius of each nest or random point. Military regimes were defined as (1) artillery position areas, (2) tracking areas, (3) inside the Impact Area, and (4) non-military (outside the OTA).

Habitat variables obtained during transect surveys at nesting areas and random points included percent vegetative cover, percent shrub cover, mean shrub height (in cm), species richness (number of plant species), and plant species diversity index ($1/\Sigma\ p_i^2$ where p_i was the proportion of the ith species in the sample; Hill 1973). At nesting areas and random points, habitat characteristics were sampled along a single 5 x 400-m strip transect and 7 50-m transects perpendicular

to the 400-m center line. At nesting areas, the nest or centroid of a nesting area where the nest was not found represented the midpoint of the 400-m transect. At Study 5 sites, the random point and starting point of the 400-m transect were the same. Percent cover, species richness, and the diversity index were estimated from point frames along the 50-m lateral transects. Field procedures used to obtain these data were described by Knick (1991).

Nest Distribution in the OTA.—In 1991 and 1992, we examined relationships between nest distribution and military activities in the OTA using information on military use from the GIS, not on actual military use during those years. In 1993, we repeated these analyses, but used information on where and when military maneuvers actually occurred.

We considered 2 types of military use: field activities and range activities. Field activities included bivouac sites, tank maneuver areas, tank tracking paths, and vehicle use of main roads. Range activities included use of stationary firing ranges along Range Road. Personnel from the Environmental Division of the Idaho Army National Guard monitored tank maneuver areas, tracking paths, and bivouac areas and recorded dates of use. Coordinates of bivouac sites were obtained using the Global Positioning System (GPS). Tank maneuver areas and tracking paths were mapped on IDARNG 1:50,000-scale topographic maps. To analyze nest distribution and road use, we obtained information on road systems from the GIS. We used only gravel roads (e.g., Pleasant Valley Road, Range Road) and main dirt roads in the analysis. Information about range activities were obtained from the IDARNG's Daily Range Log.

To examine relationships between military use and nest distribution, we represented all military use areas, road systems, nests, and random points on the GIS. Military use areas were represented as polygons. We then compared distances between occupied nests and random points and between successful and unsuccessful nests to the nearest road and military polygon. Distance comparisons were made within 2 time periods: the pre-incubation period and the incubation/brood-rearing period. We compared distances of nests and random points during pre-incubation to determine if raptors avoid military use areas when establishing nests. Similar distances during incubation and brood-rearing were compared to determine relationships between military use and nest failures.

We compared distances of nests and random points during the pre-incubation period only for burrowing owls. Sample sizes for ferruginous hawks, northern harriers, and short-eared owls were too small for statistical analysis. All military activities that occurred before the 1993 mean egg laying date for burrowing owls (9 May) were used in the analysis. These comparisons were limited to roads and range activities because tank field maneuvers did not begin until late May. We compared distances between successful and unsuccessful nests during the broodrearing period for burrowing owls, for all species pooled, and for all military activities. We used the mean egg laying date for all species combined (23 April) for the pooled analysis. All comparisons were done using t-tests.

RESULTS

Prairie Falcon Abundance and Reproduction

Abundance.—We identified 187 prairie falcon pairs in the SRBOPA in 1993, fewer than in 1992 but more than in 1990 or 1991. The number of occupied prairie falcon nesting areas was still lower than 1976 and 1977 levels when 205 and 206 pairs were found. Numbers of pairs decreased from 1992 levels in 7 10-km stretches, increased in 4, and remained the same in 8 others (Table 1).

Five 10-km units (11, 13, 15, 16, and 26) had prairie falcon densities below levels recorded from 1976-78. Three stretches (10, 17, and 24) had more pairs than observed between 1976 and 1978. The 4 10-km units in the OTA shadow (6, 7, 8, and 9) were unchanged from 1976-78 levels. We counted 73 pairs in the 8 randomly selected stretches, slightly below the 9-year average of 75.6 (Table 2). In units 7, 8, and 15 (the 3 stretches surveyed annually from 1976 through 1984 and every other year thereafter), 1993 prairie falcon densities decreased by 2 to 33 pairs, still below the long-term average of 35.4 pairs for the 3 units (Fig. 1).

The number of falcon pairs per km of canyon was still highest west of the OTA (3.25 pairs/km in units 4 and 5) and lowest east of the OTA (1.17 pairs/km in units 11, 12, and 13). The 40-km OTA

Table 1. Number of prairie falcon pairs by 10-km unit, 1990-93.

10-km Unit	1990	1991	1992	1993	Change from 1992	Change from 1976-78[a]
03	1	1	1	0	-	0
04	20	20	23	23	0	0
05	41	48	41	42	+	0
06	32	31	32	30	-	0
07	15	14	13	14	+	0
08	13	6	12	12	0	0
09	5	6	7	7	0	0
10	2	3	2	3	+	+
11	1	2	1	1	0	-
12	15	12	17	17	0	0
13	19	19	19	17	-	-
15	10	8	10	7	-	-
16	1	1	1	1	0	-
17	0	0	0	1	+	+
24	3	6	7	6	-	+
25	2	1	2	2	0	0
26	3	3	3	2	-	-
35	0	0	1	0	-	0
37	2	2	2	2	0	0
Total	185	183	194	187	+	0

[a] 0 = within the 1976-78 range
- = lower than the 1976-78 range
+ = higher than the 1976-78 range

Table 2. Number of occupied prairie falcon nesting areas in randomly selected 10-km units in the SRBOPA.

10-Km Unit	1976	1977	1978	1986	1988	1990	1991	1992	1993	$\bar{x}$
3	0	0	1	0	1	1	1	1	0	0.6
6	32	32	30	23[a]	28	32	31	32	30	30.0
7	13	12	14	12	10	15	14	13	14	13.0
8	13	12	9	10	16	13	6	12	12	11.4
15	13	13	12	13	13	10	8	10	7	11.0
24	3	4	2	2	4	3	6	7	6	4.1
26	4	5	3	1	4	3	3	3	2	3.1
37	3	3	2	3	2	2	2	2	2	2.3
Total	81	81	73	64	78	79	71	80	73	75.6

[a] Surveys of the south side of the river between the mouth of Sinker Creek and Balls Line West may have been incomplete in 1986.

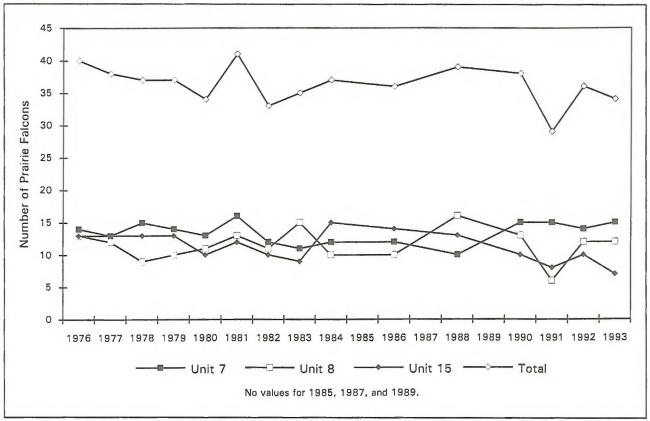

Fig. 1. Number of occupied prairie falcon nesting areas in 10-km survey units 7, 8, and 15 in the SRBOPA.

shadow (units 6, 7, 8, and 9) had intermediate densities, with 1.58 pairs/km. The difference in densities was not as great when viewed in relation to the cliff area in each stretch. The number of pairs per km² of cliff was still lowest east of the OTA (0.031), but densities in the OTA shadow (0.041) were similar to those west of the shadow (0.042).

Reproduction.—Of 202 preselected and back-up nesting areas monitored by Study 2 and 3 during the 1993 nesting season, 124 (61%) were occupied by prairie falcon nesting pairs. Occupancy rates were highest west of the OTA where 41 of 51 historical nesting areas (80%) were occupied. In the OTA shadow, 51 of 90 preselected nesting areas (57%) were occupied, and 23 of 33 ISA nesting areas east of the OTA (70%) were occupied. East of the ISA, occupancy rates were even lower: only 9 of 28 nesting areas (32%) east of the ISA were occupied.

Control pairs had a 45% nesting success rate, the lowest rate observed since 1978 (Table 3). Twenty-seven pairs bred successfully, 16 breeding pairs were unsuccessful, and breeding was not confirmed for 17 of the unsuccessful pairs. Successful control pairs fledged an average of 4.05 young, yielding an estimated 1.82 young fledged per pair, the lowest productivity recorded since 1982 (Table 3).

Breeding attempts were confirmed during incubation at 27 of the 60 occupied control nesting areas, and 14 of these pairs (52%) were successful (Table 3). Number of young fledged per attempt was 2.11, the lowest recorded since 1986 (Table 3).

Success rates of control nesting pairs in the ISA were higher than those of pairs radioed in 1993 (40% vs. 23%), and the differences approached significance ($G_1 = 2.76$, $P = 0.097$). Control pairs nesting in the OTA shadow had significantly lower success rates (23%) than pairs nesting east and west of the shadow (52%; $G_1 = 4.56$, $P = 0.033$). The difference in OTA shadow success rates (16%) and non-shadow success rates (47%) were even more extreme when radio and control pairs were pooled ($G_1 = 8.94$, $P = 0.003$). Mean number of young fledged per successful pair did not differ significantly among the east $\bar{x} = 3.63$, west $\bar{x} = 4.39$, and shadow $\bar{x} = 4.33$ areas (ANOVA $F_{2,27} = 1.17$, $P = 0.32$).

Table 3. Nesting success and productivity of prairie falcons in the SRBOPA, 1974-93. Sample sizes are in parentheses.

Year	% of Pairs Successful	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged/ Attempt [a]	# Fledged/ Pair [b]
1974	73% (15)	64% (11)	3.94 (17)	2.52	2.88
1975	83% (23)	86% (21)	3.74 (27)	3.21	3.10
1976	74% (23)	79% (29)	4.00 (41)	3.16	2.96
1977	57% (14)	67% (27)	4.08 (25)	2.73	2.33
1978	45% (20)	18% (17)	3.29 (17)	0.59	1.48
1979	70% (40)	75% (32)	3.73 (30)	2.80	2.61
1980	59% (49)	65% (54)	4.03 (36)	2.62	2.38
1981	80% (51)	83% (46)	4.04 (22)	3.35	3.23
1982	46% (26)	69% (26)	3.53 (17)	2.44	1.62
1983	71% (31)	73% (26)	3.24 (17)	2.36	2.30
1984	— —	88% (16)	3.95 (19)	3.48	—
1985	— —	93% (14)	4.08 (13)	3.79	—
1986	— —	44% (18)	3.43 (7)	1.51	—
1987	— —	72% (36)	4.32 (31)	3.11	—
1988	— —	78% (9)	3.86 (7)	3.01	—
1989	— —	83% (6)	3.67 (6)	3.05	—
1990	— —	74% (19)	4.06 (18)	3.00	—
1991	81% (42)	94% (16)	4.08 (24)	3.84	3.11
1992	75% (56)	85% (34)	4.17 (30)	3.54	3.13
1993	45% (60)	52% (27)	4.05 (22)	2.11	1.82
$\bar{x}$ All Years	66% SD = 14%	72% SD = 18%	3.86 SD = 0.30	2.81 SD = 0.77	2.54 SD = 0.60

[a] Calculated as the product of % attempts successful and # fledged/successful attempt.
[b] Calculated as the product of % of pairs successful and # fledged/successful attempt. Data are not available for 1984-90 because prairie falcon pairs were not preselected in those years.

Female fledging weights averaged 785 g (n = 22; SD = 48) inside the shadow and 790 g (n = 29; SD = 81) east and west of the shadow. Male weights averaged 554 g (n = 12; SD = 14) inside the shadow and 556 g (n = 33; SD = 36) outside the shadow. Analyses of variance using length of seventh primary as a covariate found no significant differences in weights inside vs. outside the shadow for either females ($F_{1,48} < 0.001$; $P = 0.99$) or males ($F_{1,42} = 0.009$; $P = 0.92$).

Dispersal and Nest Site Fidelity.—Twenty-one prairie falcons radioed as breeding adults by Study 2 between 1990 and 1992 were encountered in 1993 (Table 4). Seventeen were still wearing radios. Nine of the 21 falcons encountered in 1993 were individually identified. Of these, 4 were trapped, 3 were identified by radio signal, 1 was found dead, and 1 was identified by reading its color band code through a spotting scope. Three of 4 falcons that were trapped had shed their radios. The third falcon was still wearing its radio when it was trapped in the OTA on 16 January 1993. The radio was removed before the bird was released. One falcon that had been equipped with a tail-mounted transmitter in 1990 was found dead in the OTA on 11 August 1993. Remains consisted of feathers and bones only, no radio was seen. The bird appeared to have been dead for at least a few months.

Of 9 falcons identified by their leg bands or radio signals, 2 occupied the same nesting area where they were radioed, and 4 occupied adjacent nesting areas (Table 4). The breeding status of the remaining 3 falcons was not known. Of 12 falcons not identified to individual, 5 may have occupied the same nesting areas, and 5 may have occupied adjacent nesting areas. One male falcon was observed in its original nesting area and an adjacent nesting area (Thirst Draw DS and Thirst Draw). A radioed male falcon was seen at the Peregrine Cliff nesting area on 1 occasion in late March 1993. A male falcon was radioed at this nesting area in 1992. However, the nesting area was vacant in 1993. The falcon observed in March might have been the 1992 occupant, but it did not breed in the nesting area in 1993. The radio signal of a

Table 4. Encounters with prairie falcons radioed as breeding adults prior to 1993.

Year Radioed & Nesting Area	Band Number	Sex	1993 Nesting Area[a]	Status	1993 Status of Original Radio Site[b]
Beecham 1991	816-70256	♂	Beecham	Trapped-had shed radio.	
Beercase Downstream 1992	1807-38562	♀	Beercase Draw	Sighted-radio working.	New ♀ paired w/unknown ♂
Bitch 1991	816-70262[c]	♂	Bitch	Sighted-wearing a radio.	
Black Butte Ferrug 1992	816-70287[c]	♂	CSJ Jr.	Sighted-wearing a radio.	Vacant
Cabin 1991	1807-01229[c]	♀	Cabin	Sighted-wearing a radio.	
Crane Falls I 1990	816-70248	♂	A-58	Trapped-had shed radio.	Vacant
Fang Downstream 1992	816-74855[c]	♂	Fang	Sighted-wearing a radio.	Vacant
Falcon Flats Cave East 1992	816-74857[c]	♂	Falcon Flats Cave East	Sighted-wearing a radio.	
Falcon Flats Engine 1992	816-70286	♂	unknown	Trapped-had shed radio.	Occupied by unknown pair
Fawn Humpback 1991	816-70250[c]	♂	Fawn Loaf	Sighted-wearing a radio.	Vacant
Massacre Face 1992	1807-38653[c]	♀	Massacre Face	Sighted-wearing a radio.	
Ogden GE77 1992	1807-38662[c]	♀	Hell Hole Gate	Sighted-wearing a radio. Signal received from general area.	New? ♀ paired w/unknown ♂
Ogden Rock 1992	1807-38668	♂	Ogden Rock Upstream	Sighted-radio working.	New ♂ paired w/unknown ♀
Ogden Rock Downstream 1991	1807-01221	♀	Ogden Rock Downstream	Sighted-radio not working.	
Peregrine Cliff 1992	816-70165	♂	unknown	Sighted transient-wearing a radio.	Vacant
Petroglyphs 1992	1807-01298	♀	Conning Tower	Sighted-radio working.	New ♀ paired w/unknown ♂
Shoofly 1990	1807-01211	♀	unknown	Found dead-had shed radio.	Vacant
Slide II 1992	816-70291[c]	♂	Slide I	Sighted-wearing a radio.	Vacant
Thirst Draw DS 1992	816-74716[c]	♂	Thirst Draw or Thirst Draw DS	Sighted-wearing a radio.	New? ♂ w/unknown ♀
Tom Draw 1992	1807-01299[c]	♀	Tom Draw	Sighted-wearing a radio.	
Powerline Mirror 1991	816-70251	♂	unknown	Trapped-radio removed.	Occupied by unknown pair

[a] Unless unknown, these sites are at, or adjacent to, nesting area where radioed.
[b] Blank if it is known or assumed the bird returned to the nesting area.
[c] Band number of 1993 bird not confirmed. Number is for bird from original radioed site.

female falcon captured in 1992 at the Ogden GE77 nesting area was detected in late March 1993, but she was not located visually. A radioed female falcon was observed in late May at the adjacent Hell Hole Gate nesting area, so we suspect she nested there in 1993.

Two falcons (the male at Bitch and female at Cabin) probably occupied the same nesting areas from 1991 to 1993. Falcons were radioed in both nesting areas in 1991. Radioed falcons of the same sex were then observed in both nesting areas in 1992 and 1993. We did not identify these birds individually in either year, but suspect they are the 1991 occupants.

In addition to the radioed falcons, researchers captured or observed marked adults at 6 other nesting areas in 1993 (Table 5). All were banded as nestlings in the SRBOPA. Four falcons were

trapped and radioed at their 1993 nesting area 5.8 to 6.4 km from their natal nesting areas. Two falcons banded as nestlings in the SRBOPA were trapped and radioed but apparently did not breed in the SRBOPA. A female caught at Cattleguard Upstream, 5.4 km from its natal area, was not seen in this nesting area again after its capture. Its radio signal was detected 3 times in March and April, but the bird was not associated with a nesting area. A female caught at the Strike II nesting area, 11.1 km from its natal area, was not seen again at that nesting area. Study 2 personnel did not detect its radio signal in the SRBOPA after the day it was trapped, so we believe the bird was a transient.

Four falcons banded as nestlings in the SRBOPA were found dead in 1993. In March, a bird that fledged from the 1992 China South nesting area was found well decomposed near Picabo, Idaho 145 km from its natal area. This bird was probably electrocuted on an electric distribution line. In April 1993, a bird that fledged from the 1992 Ogden Rock Downstream nesting area was found near Vale, Oregon 101 km from its natal area. This bird was relatively fresh and apparently died of electrocution. In August 1993, the leg of a 1987 nestling from Mother Giant Upstream was found in a woodrat (*Neotoma* spp.) nest 5.6 km from its natal area. Finally, the leg of a 1993 fledgling from the Point nesting area was found in November in a great horned owl (*Bubo virginianus*) nest 1.8 km from its natal area. These recoveries are in addition to those reported for nestling prairie falcons banded and radioed in 1993 by McFadzen and Marzluff (this volume).

Table 5. Band sightings and recoveries of prairie falcons banded as nestlings in the ISA reported in 1993.[a]

Natal Nesting Area and Year	Band Number	Sex	Status	Date	Distance Moved (km)	Location Reported
Balls Basin GE 1991	1807-01272	♀	Trapped and radioed.	24 Apr	5.8	Rosie Draw
Balls Basin Hamer 1991	816-70276	♂	Trapped and radioed.[b]	16 Mar	7.1	Priest IV
Bitch 1991	1807-01285	♀	Trapped and radioed.	16 Mar	5.4	Cattleguard upstream-transient
China South 1992	816-74802	♂	Trapped and radioed.	28 Apr	11.1	Strike II-transient
Spoon Upstream 1991	816-74762	♂	Trapped and radioed.	15 Apr	6.4	Jackass BBGE
Tick II 1990	816-74726	♂	Trapped and radioed.	8 Apr	6.3	Tom Butte West
Mother Giant Upstream 1987	816-70181	U	Dead—Found leg w/band in a woodrat nest.	10 Aug	5.6	San Sebastian Cavern
Point 1993	1807-47811	U	Dead—Found leg w/band in a great horned owl nest.	11 Nov	1.8	Hoot Owl Draw
China South 1992	1807-38611	U	Dead—electrocuted, well decomposed.	1 Mar	145	Picabo, ID
Ogden Rock Downstream 1992	1807-38648	U	Dead—possible electrocution, recent.	12 Apr	101	Vale, OR

[a] These recoveries are in addition to those in Table 4.
[b] Retrapped in the fall in the OTA, radio still working.

Golden Eagle Abundance and Reproduction

Abundance.—In 1993, golden eagle pairs occupied 29 (74%) of the 39 preselected nesting areas in the SRBOPA and 20 (87%) of the 23 preselected nesting areas in the Comparison Area. The number of occupied nesting areas in the SRBOPA was 1 fewer than in 1992; the same as in 1991; and, 4 fewer than in 1973, 1974, and 1976 (Table 6). Number of pairs varied from 33 to 35 between 1971 and 1977, then dropped and fluctuated from 28 to 32 between 1978 and 1988. Since 1989, the number of pairs has held steady at 29 to 30, down 5 or 6 from the early 1970's. A linear regression showed that the number of eagle pairs had declined significantly from 1971-93: (# pairs = 51.5-0.24* year ($r^2 = 0.58$, $P < 0.001$).

Of the 13 vacant nesting areas in the SRBOPA and Comparison Area, 6 have not been occupied since 1982 or earlier. Of these, 4 in the SRBOPA (A56, Bruneau Bridge, Bruneau Flats, and Simpkin) have been vacant for 11, 13, 16, and 15 years, respectively. In addition, a stretch of canyon that formerly contained 2 adjacent nesting areas (Delates Delight and Pump Station) has been occupied by only 1 pair for the last 16 years. Two vacant nesting areas (Strike II and Swan Dam) were vacant for the fifth consecutive year, and eagles have used the nesting areas associated with the PP&L 125 and PP&L 102 towers only 1 year each. Some vacant nesting areas appear to have been absorbed by adjacent pairs (Lehman et al. 1992).

Reproduction.—Golden eagle reproduction in the SRBOPA was higher than in any year since 1982 (Table 6). Percent of pairs breeding increased from 86% in 1992 to 90% in 1993, the same level observed in 1991. Percent of breeding attempts successful increased from 56% to 80% between those years. The number of young fledged per successful nesting attempt decreased slightly from 1.73 to 1.71, and number of young fledged per pair increased from 0.83 to 1.23 between 1992 and 1993.

In 1993, productivity (young fledged per pair) in the Comparison Area was nearly the same as in

Table 6. Nesting success and productivity of golden eagles in the SRBOPA, 1971-93. Sample sizes are in parentheses.

Year	# Occupied Nesting Areas	% of Pairs Breeding	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged/Pair[a]	Total Fledged
1971	34	100% (31)	62% (21)	1.89 (19)	1.17	40
1972	34	— —	— —	1.64 (11)	—	—
1973	35	65% (34)	44% (18)	1.38 (8)	0.40	14
1974	35	67% (33)	53% (17)	1.50 (10)	0.53	19
1975	33	75% (32)	56% (18)	1.45 (11)	0.61	20
1976	35	68% (34)	50% (16)	1.60 (10)	0.54	19
1977	34	82% (34)	59% (17)	1.50 (10)	0.73	25
1978	32	72% (32)	77% (13)	1.70 (10)	0.98	31
1979	30	97% (30)	63% (24)	1.40 (15)	0.86	26
1980	31	87% (31)	76% (21)	1.78 (18)	1.18	37
1981	30	100% (30)	73% (22)	1.74 (19)	1.27	38
1982	30	87% (30)	79% (24)	2.00 (18)	1.38	41
1983	28	96% (27)	67% (18)	1.57 (14)	1.01	28
1984	31	— —	59% (17)	1.56 (9)	0.64[b]	19
1985	32	38% (32)	42% (12)	1.00 (4)	0.16	5
1986	29	55% (29)	40% (14)	1.20 (5)	0.26	8
1987	32	78% (32)	32% (25)	1.38 (8)	0.34	11
1988	32	74% (31)	52% (23)	1.54 (13)	0.59	19
1989	30	80% (30)	63% (19)	1.36 (14)	0.69	21
1990	30	87% (30)	80% (25)	1.65 (20)	1.15	34
1991	29	90% (29)	74% (13)	1.59 (17)	1.06	31
1992	30	86% (29)	56% (16)	1.73 (11)	0.83	25
1993	29	90% (29)	80% (15)	1.71 (14)	1.23	36
$\bar{x}$	31.5	80%	61%	1.56	0.81	25
SD	2.2	15.4	14.0	0.22	0.36	10.6

[a] Based on % of pairs breeding, % of attempts successful, and # fledged/successful attempt.
[b] Based on % of pairs successful and # fledged/successful attempt.

Table 7. Nesting success and productivity of golden eagles in the Comparison Area, 1971-93. Sample sizes in parentheses.

Year	% of Pairs Breeding	% of Attempts Successful	# Fledged/ Successful Attempt	# Fledged/ Pair
1971	100% (22)	44% (16)	1.54 (13)	0.67
•	•	•	•	•
1973	43% (21)	88% (8)	1.38 (8)	0.52
1974	47% (19)	75% (8)	1.50 (6)	0.53
1975	83% (18)	60% (10)	1.43 (7)	0.71
1976	74% (19)	83% (6)	1.56 (9)	0.96
1977	89% (18)	60% (5)	1.89 (9)	1.01
1978	68% (22)	64% (14)	1.89 (9)	0.82
•	•	•	•	•
•	•	•	•	•
•	•	•	•	•
1986	58% (19)	67% (9)	1.43 (7)	0.56
1987	94% (18)	44% (18)	1.14 (7)	0.47
1988	95% (20)	71% (17)	1.50 (14)	1.01
1989	84% (19)	63% (16)	1.50 (10)	0.79
1990	89% (19)	59% (17)	1.64 (11)	0.86
1991	95% (19)	85% (13)	2.00 (13)	1.62
1992	95% (21)	63% (16)	1.73 (11)	1.04
1993	85% (20)	71% (17)	2.09 (11)	1.26
$\bar{x}$	80%	66%	1.61	0.86
SD	18	13	0.26	0.32

the SRBOPA (Tables 6 and 7). At least 2 pairs in the Comparison Area fledged 3 chicks in 1993; no SRBOPA pairs produced 3 young. Productivity has been higher in the Comparison Area in 12 of the 15 years when intensive surveys were conducted in the Comparison Area (Tables 6 and 7). Long-term productivity in the Comparison Area ($\bar{x}$ = 0.83 young fledged per pair) has not differed significantly (Paired t_{14} = 1.62, P = 0.13) from that in the SRBOPA in those same years ($\bar{x}$ = 0.74 young fledged per pair).

Golden Eagles and Wildfire.—We examined 35 historical golden eagle territories: 15 in the high burn category (>40% of the area burned since 1980 within a 2.6-km radius of the nesting area) and 20 in the low burn category (<40% of the area burned). Of the 35 historic territories, 8 were vacant for >3 of the 13 years between 1981 and 1993. All 8 were vacant in 1993, and 5 of the 8 were in the high burn category. Of the 3 vacant territories in the low burn category, 2 contained >20% agriculture within the 2.6-km radius (high agriculture category). Four of 8 territories became vacant since 1982, and 3 were in the high burn category. The other 4 territories were vacant prior to 1980 and may be permanently lost (i.e., vacant 13-16 years). Two of these territories were in the high agriculture category, and the other 2 were in high burn categories. Of the 35 nesting areas, 10 failed to produce young in ≥10 of the 13 years. Of these 6, were in the high burn category and 2 were in the low burn, high agriculture category.

Dispersal and Nest Site Fidelity.—In 1993, 5 of 7 golden eagles radioed in previous years by Study 2 bred in their 1992 nesting areas. The female that nested in the Grand View Sand Cliff territory in 1992 moved 14.4 km upstream and bred successfully with an unidentified male at the Pole 369 nesting area in 1993. The male that bred at the PP&L 119 nesting area in 1991 and 1992 was not seen in 1993. A new male was present at PP&L 119, but the pair did not lay eggs.

Two golden eagles banded as nestlings in the SRBOPA were observed in 1993. On 18 October, a BLM biologist observed an adult eagle with a yellow right wing marker 4 km northeast of the Mudflat nesting area. The bird was not identified to individual but was wing marked either prior to 1977, or by Study 2 in 1992. The Mudflat nesting area is outside the study area, so it was not surveyed in 1993. On 25 September, Morlan Nelson found an injured golden eagle near Walters Butte. This bird was banded and wing

marked at the Strike I nesting area in 1980, but had shed its yellow-blue right wing marker. The bird may have nested at Walters Butte since at least 1988, as a similarly-marked adult was observed in the nest in 1988 and 1991. The eagle is recovering and is scheduled for release in December. A third marked eagle observed in 1993 could not be identified. An eagle nesting at the Narrows nesting area was banded with a USFWS leg band, but no attempt was made to read the band.

Ferruginous Hawk Abundance and Reproduction

In 1993, 25 (41%) of 61 historical ferruginous hawk nesting areas surveyed in the SRBOPA were occupied (Table 8). These included 9 canyon, 13 bench, and 3 non-ISA nesting areas. Twelve of 17 non-OTA nesting areas (71%) were occupied, but only 1 of 4 OTA nesting areas (25%) were occupied. Only 1 occupied nesting area not previously recorded was found in 1993 (PP&L 107), compared to 10 new nesting areas found in 1992.

In the SRBOPA, breeding attempts were confirmed at 18 nesting areas (Table 9). These included 5 canyon, 12 bench, and 1 non-ISA nesting areas. Twelve (67%) of the breeding attempts were confirmed during incubation: 3 in the canyon, 8 on the bench, and 1 outside the ISA. Only 7 of the 12 SRBOPA nesting areas (58%) were successful: 5 bench, 1 canyon, and 1 non-ISA nest. One of the 8 benchland nesting attempts was in the OTA, and it failed. Five of the 7 nesting attempts outside the OTA (71%) were successful. However, if the OTA category is expanded to include pairs that have nests outside the OTA boundary but generalized home ranges that include the OTA (see Kochert et al. 1991), the nesting success rate for the OTA increases. Then, 6 of 8 benchland nesting attempts included part of the OTA, and 3 (50%) were successful. The 2 remaining nesting areas completely outside the OTA were successful.

Ferruginous hawk reproduction in the SRBOPA was higher than in 1992 (Table 10). Percent of pairs laying eggs decreased slightly between 1992 and 1993, but proportion of breeding attempts successful increased from 33% to 58%. Productivity in the SRBOPA in 1993 compared favorably with earlier years. Mean young fledged per pair was higher than that in 1977-1979, similar to that in 1985, and lower than that recorded in 1980 and 1981.

We assessed burn effects at 61 ferruginous hawk nesting areas surveyed in 1992. Five nesting areas in the OTA were excluded due to lack of burn data. Mean percent of the area burned within a 1.5-km radius of the 1992 nest (or the coordinates from the year most recently occupied) was 53% for vacant nesting areas and 40% for occupied nesting areas. In a categorical analysis, occupancy of ferruginous hawk nesting areas with <50% of the area burned did not differ significantly from that of nesting areas with >50% of the area burned ($G_1 = 1.351$, $P = 0.245$).

Table 8. Number of occupied historical ferruginous hawk nesting areas in the SRBOPA, 1993. Numbers in parentheses are sample sizes.

Area	# Historical Nesting Areas	% Historical Nesting Areas Occupied
Canyon	31	29% (9)
Bench	21	62% (13)
Non-ISA	9	33% (3)
SRBOPA	61	41% (25)

Table 9. Nesting success of ferruginous hawks in the SRBOPA, 1993. Sample sizes are in parentheses.

Area	# Breeding Attempts[a]	% Breeding Attempts CDI[b]	% Attempts Successful CDI[b]
Canyon	5	60 (3)	33
Bench	12	67 (8)	63
Non-ISA	1	100 (1)	100
SRBOPA	18	67 (12)	58

[a] with known outcomes.
[b] CDI = confirmed during incubation.

Table 10. Nesting success and productivity of ferruginous hawks in the SRBOPA, 1977-93. Sample sizes are in parentheses.

Year	% of Pairs Breeding	% Attempts Successful	Young/ Successful Attempt	% Pairs Successful[a]	# Fledged/ Pair[b]
1977	92 (12)	27 (11)	1.50 (2)	25 (12)	0.37
1978	83 (12)	43 (7)	3.00 (4)	33 (12)	1.07
1979	60 (15)	67 (9)	2.83 (6)	40 (15)	1.14
1980	70 (17)	92 (12)	2.70 (10)	65 (17)	1.76
1981	100 (6)	62 (8)	2.80 (5)	71 (7)	1.74
"	"	"	"	"	"
"	"	"	"	"	"
"	"	"	"	"	"
1985	95 (20)	56 (25)	2.67 (12)	52 (21)	1.42
"	"	"	"	"	"
"	"	"	"	"	"
"	"	"	"	"	"
1992	95 (21)	33 (15)	2.80 (5)	44 (23)	0.88
1993	84 (19)	58 (12)	3.00 (10)	46 (24)	1.46

[a] Based on preselected pairs.
[b] Based on % of pairs laying eggs, % of attempts successful, and # fledged/successful attempt.

Nesting of Raptors on the Benchlands

General Survey Results.—In 1993, we located 106 occupied raptor nesting areas on benchlands in the ISA (Table 11), 12 more than in 1992. Twenty-five were inside the OTA, and 81 were outside the OTA. These included 14 ferruginous hawk, 10 northern harrier, 71 burrowing owl, and 11 short-eared owl pairs. Thirty-nine of the 106 pairs were found during historical nest surveys, 23 were found during quadrat surveys, and 44 were found incidentally by Study 3 personnel and other study teams.

On a unit area basis, we found 4.4 nesting areas per 100 km^2 inside the OTA and 5.6 per 100 km^2 outside the OTA. However, 6 nesting areas considered outside the OTA for this analysis were on or very near the OTA boundary. These included 5 ferruginous hawk nests on or near the PP&L transmission line, which forms the OTA's northern boundary, and 1 short-eared owl nesting area within 100 m of the boundary. If these nesting areas are considered inside the OTA for the analysis, 5.5 nesting areas per 100 km^2 were found inside the OTA, and 5.2 nesting areas per 100 km^2 were found outside the OTA.

We checked 145 historically occupied nesting areas on ISA benchlands, 142 of which were surveyed sufficiently to determine occupancy. Forty-seven historical nesting areas were occupied. Occupancy rates at historical nesting areas inside and outside the OTA differed only slightly.

Table 11. Number of occupied raptor nesting areas found on ISA benchlands in 1993 using different survey methods. Numbers in parentheses indicate percent of nesting areas found by each method.

Survey Type	Ferruginous Hawk	Northern Harrier	Burrowing Owl	Short-Eared Owl	Totals
Historical	12 (86)	4 (40)	10 (27)	4 (36)	39 (37)[a]
Quadrat	1 (7)	4 (40)	13 (18)	5 (46)	23 (22)
Incidenta	1 (7)	2 (20)	39 (55)	2 (18)	44 (41)
Totals	14	10	71	11	106

[a] Forty-seven historical nesting areas were occupied, but 8 were found during quadrat surveys or incidentally.

Twenty-eight (36%) of historical nesting areas inside the OTA were occupied, compared to 114 (32%) of nesting areas outside the OTA. In 1993, we determined fate at 92 of 94 nesting areas occupied in 1992. Forty (43.5%) of these were reoccupied in 1993.

One of the 14 ferruginous hawk nesting areas on the benchlands (PP&L 107) was newly established in 1993. Of 12 ferruginous hawk nesting areas where breeding attempts were confirmed, 1 was on a rock outcrop, 1 was on the ground, 6 were on transmission towers or poles, and 3 were on artificial platforms. The nest for 1 breeding attempt where fledged young were observed (PP&L 111) was not located, but we suspected it was on the ground.

Four of 10 occupied northern harrier nesting areas in the ISA benchlands had not been previously recorded. Two were found during quadrat surveys, and 2 were found incidentally. Three of 5 nests found were in thickets of dead Russian thistle. Two nests were in tall grass and weeds in fallow agricultural fields.

Six of 11 occupied short-eared owl nesting areas and 48 of 71 burrowing owl nesting areas on the ISA benchlands had not been previously recorded. Of these, 5 short-eared owl nesting areas and 12 burrowing owl nesting areas were found during quadrat surveys. Of 3 short-eared owl nests found, 2 were in stands of big sagebrush (*Artemisia tridentata*), and 1 was in a fallow field. All burrowing owl nests except 2 were in ground-level burrows. One burrow in the Impact Area was excavated on top of an artificial berm supporting a moving target system, and 1 was on the side of an excavation berm.

We used call playback at 25 historical burrowing owl nesting areas, but only 7 of these were occupied. At 1 nesting area a burrowing owl flew toward the observer. At a second nesting area an owl flushed and flew away from the observer. At 2 nesting areas owls did not respond though we knew birds were present. We also used call playback during 7 of the May and June quadrat surveys, but owls responded only once. On that occasion, a pair of owls called and flew toward the observer.

Relative Abundance.—Forty-nine quadrats (20 inside and 29 outside the OTA) were surveyed on ISA benchlands in 1993. Forty-eight quadrats were surveyed twice, and 1 quadrat was surveyed once. Twenty-nine of 106 occupied nesting areas on the benchlands were inside quadrats, but only 23 (22%) were first detected during quadrat surveys. Nine of these were inside the OTA, and 14 were outside the OTA (Table 12).

In 1993, burrowing owls were the most abundant of the 4 species found inside quadrats, accounting for 13 of the 23 nesting areas found. We also found 1 ferruginous hawk, 5 short-eared owl, and 4 northern harrier nesting areas. We found 0.45 nesting areas per quadrat inside the OTA compared to 0.48 nesting areas outside the OTA; contingency table analysis of quadrats with and without nesting areas suggested that frequencies of occupied nesting areas in the 2 areas did not differ ($G_1 = 0.16$, $P = 0.69$).

Five nesting areas were missed during the first quadrat survey, and 1 was found incidentally prior to the first survey. Of the 5 nesting areas missed, 2 were found during the second quadrat survey. One short-eared owl and 2 burrowing

Table 12. Number of occupied raptor nesting areas found on ISA benchlands during quadrat surveys. Numbers in parentheses show the number of occupied nesting areas found per quadrat.

Species	Inside OTA ($n = 20$)	Outside OTA ($n = 28$)	Totals ($n = 48$)
Ferruginous Hawk	0	1	1
Northern Harrier	1	3	4
Burrowing Owl	6	7	13
Short-eared Owl	2	3	5
Total	9 (0.45)	14 (0.50)	23 (0.48)

owl nesting areas were missed during both quadrat surveys.

The relatively low number of nesting areas first detected during quadrat surveys (23 of 106) suggests that raptor nests on the bench are more likely to be encountered incidentally or at historically occupied nesting areas than within random plots. In comparison, 39 occupied nesting areas were found at 142 historical nesting areas, and 44 were found incidentally. A total of 853 hrs of effort was spent during quadrat surveys, or 37 hrs per occupied nesting area. We spent an average of 8.8 hrs per quadrat inside the OTA and 8.9 hrs per quadrat outside the OTA; yet we found nests in only 20 of 48 quadrats. Surveys of 32 quadrats in 1990, 768 transects and circular plots in 1991, and 44 quadrats in 1992 also showed a low return per unit effort for random plot surveys (Lehman et al. 1990, Steenhof et al. 1991, and Lehman et al. 1992).

Nesting Success.—In 1993, breeding was confirmed at 53 of 106 occupied nesting areas on ISA benchlands. These included 12 ferruginous hawk, 7 northern harrier, 31 burrowing owl, and 3 short-eared owl nesting areas. Of the 53 nesting areas where breeding was confirmed, 36 were found during incubation. Twenty-four of these were successful, and 8 were unsuccessful. Nesting success was not determined at 4 of these nesting areas. Of 12 ferruginous hawk nesting areas where breeding was confirmed, 8 were found during incubation (Table 13). Of these, 5 were successful and 3 failed. All 5 successful nesting areas were outside the OTA. The only nesting attempt in the OTA failed. Of 7 northern harrier nesting areas where breeding was confirmed, 5 were found during incubation (Table 13). Four of these 5 nesting attempts failed. The only successful nesting attempt was outside the OTA. Two of the 4 unsuccessful nesting areas were in the OTA.

Of 63 occupied burrowing owl nesting areas where fate was determined, 27 were successful and 36 were unsuccessful (Table 13). We found 46 of these pairs during incubation or before 6 June. Of these, 18 (39.1%) were successful and 28 (60.9%) were unsuccessful. Of the 28 unsuccessful nesting areas, 8 were in the OTA, and 20 were outside the OTA. Four of 12 nesting areas (33.3%) inside the OTA were successful compared to 14 of 34 (41.2%) outside the OTA; differences were not significant ($G_1 = 0.23$, $P = 0.63$).

Small sample sizes prevented an analysis of nesting success inside and outside the OTA for short-eared owls. Fate was determined at only 2 of 3 nesting areas where breeding was confirmed. Only 1 of these was found during incubation. This pair failed to raise young. The second pair was successful, but was found late in the breeding period (Table 13). The only successful short-eared owl nest was in the OTA.

Habitat Assessments.—G-tests involving 18 categorical variables revealed significant differences between nesting areas and random points. Nesting areas tended to be on flatter ground, were nearer to agricultural developments and roads, had more artificial perches and nest structures, and were on deeper soil sites, than randomly selected points (Table 14). Also, fewer nesting areas were north of the drift fence (spring-fall grazing) than random points. The tendency of nesting areas to be nearer roads than random points probably indicates a survey bias rather than a preference by raptors for such locations. Variables not important in discriminating

Table 13. Nesting success of breeding raptors on ISA benchlands.

	Successful Nesting Areas		Unsuccessful Nesting Areas		
	Found During Inc.	Found After Inc.	Found During Inc.	Found After Inc.	Totals
Ferruginous Hawk	5	4	3	0	12
Northern Harrier	1	2	4	0	7
Burrowing Owl	18	9	28	8*	63
Short-eared Owl	0	1	1	0	2
Totals	24	16	8	0	48

Table 14. Habitat characteristics at benchland sample points for the categorical variables analyzed in 1993. Percentages indicate the proportion of nesting areas and random points exhibiting each characteristic.

Variable[a]	Nesting Area %	Random Point %	G_1[b]	*P*
HILLS50	14.3	26.8	4.92	0.030
AG500	26.7	13.4	5.60	0.020
PERCH50	24.8	8.2	10.30	0.001
PERCH100	31.4	16.4	6.23	0.001
ROAD50	51.4	35.0	5.53	0.019
ARTS50	21.9	1.0	25.74	<0.001
ARTS100	22.8	2.1	22.74	<0.001
GRAZING	50.5	63.9	3.73	0.053
SOIL DEPTH	89.1	71.2	16.80	<0.001

[a] HILLS50 = presence of hills within 50 m; AG500 = presence of agricultural development within 500 m; PERCH50 and PERCH100 = presence of artificial perches within 50 m and 100 m; ROADS50 = presence of roads within 50 m; ARTS50 and ARTS100 = presence of artificial nest structures within 50 m and 100 m; GRAZING = north or south of the drift fence (values shown are for north of the fence = spring - fall range); SOIL DEPTH = shallow, medium, deep (values shown are for medium and deep soils combined).

[b] Degrees of freedom in all cases = 1

between the 2 groups included vegetative cover class (open or closed), landform (basalt or other), and soil development (weak or strong).

Separate analyses by species showed that differences in the occurrence of hills near nests and random points were significant only for burrowing owls. Only 13 percent of burrowing owl nests were near hills and buttes compared to 27% for random points ($G_1 = 4.99$, $P = 0.02$). The tendency to nest in deeper soil sites was also significant only for burrowing owls ($G_1 = 8.41$, $P = 0.004$). The occurrence of nests near artificial nest structures and perches was significant for all species (G_1's > 4.25, P's < 0.04), but more so for ferruginous hawks (G_1's > 23.58, P's < 0.001) and for burrowing owls (G_1's > 9.19, P's < 0.002). All species except the northern harrier were found close to roads (G_1's > 3.69, P's < 0.05). The occurrence of nests near agricultural development was significant for all species (G_1's > 3.74, P's < 0.05) except the short-eared owl ($G_1 = 1.29$, $P = 0.26$). However, the tendency to nest in closed habitat types was significant only for short-eared owls ($G_1 = 10.34$, $P = 0.001$).

T-tests involving 7 continuous variables revealed significant differences between nesting areas and random points in 2 vegetation categories. Percent vegetative cover at nesting areas was significantly higher than at random points ($\bar{x} = 66.3$, $\bar{x} = 57.4$, $t_{209} = 3.71$, $P < 0.001$). Mean shrub height (in cm) at nesting areas was also higher ($\bar{x} = 26.4$, $\bar{x} = 20.2$, $t_{200} = 3.71$, $P = 0.03$). Percent shrub cover and the diversity index were not significantly higher at nesting areas than at random points (percent shrub cover: $\bar{x} = 6.5$, $\bar{x} = 5.5$, $t_{200} = 0.81$, $P = 0.42$; diversity index: $\bar{x} = 3.2$, $\bar{x} = 3.1$, $t_{200} = 0.60$, $P = 0.55$). Other variables not useful in discriminating between the 2 groups were the number of rock outcrops, vegetative species richness, and proportion of the nesting area or random plot lying within various military regimes (tracking areas, firing areas, impact area, and outside the OTA).

When analyzed by species, we found significant differences in 3 vegetation categories. Percent vegetative cover at nesting areas was higher than at random points for ferruginous hawks and burrowing owls ($\bar{x} = 67.7$, $\bar{x} = 57.4$, $t_{109} = 3.91$, $P = 0.001$; $\bar{x} = 66.9$, $\bar{x} = 57.4$, $t_{165} = 2.5$, $P = 0.02$, respectively). Percent shrub cover was significantly higher at northern harrier and short-eared owl nesting areas ($\bar{x} = 11.8$, $\bar{x} = 5.5$, $t_{105} = 2.24$, $P = 0.03$; $\bar{x} = 17.2$, $\bar{x} = 5.5$, $t_{106} = 2.52$, $P = 0.03$). Mean shrub height was significantly higher at short-eared owl nesting areas ($\bar{x} = 34.3$, $\bar{x} = 20.1$, $t_{106} = 2.08$, $P = 0.04$).

The average number of rock outcrops within 100 m of ferruginous hawk nests was significantly greater at nesting areas than at random points ($\bar{x}$ = 0.92, $\bar{x}$ = 0.14, S = 951.5, P = 0.02). No rock outcrops were found within 100 m of burrowing owl or short-eared owl nesting areas. Three of 10 northern harrier nesting areas had at least 1 rock outcrop nearby.

Among categorical variables, comparisons of successful and unsuccessful pairs for all species pooled showed few significant relationships. More successful pairs (37%) nested on or within 50 m of an artificial nest structure than unsuccessful pairs (11.4%; G_1 = 0.04, P = 0.003). This relationship also held for birds nesting on or within 100 m of a nest structure (34.1% vs. 15.9%; G_1 = 3.84, P = 0.05). Thirty-two percent of successful pairs nested within 50 m of an artificial perch, but the difference was not significant because many unsuccessful pairs (24.4%) also had perches nearby. Among continuous variables, only mean shrub height differed significantly between successful and unsuccessful nesting areas when species were pooled. Mean shrub height at successful nesting areas averaged 30.3 cm compared to 21.6 cm at unsuccessful nesting areas (t_{83} = 1.94, P = 0.05). Because of small sample sizes of most species, we analyzed a breakdown of success in relation to habitats only for burrowing owls. A significant relationship was found only in the vegetative cover class. Successful pairs nested in closed habitats 91.6 % of the time compared to 70.4% for unsuccessful pairs (G_1 = 4.88, P = 0.03). An analysis for burrowing owls showed no significant relationships among continuous variables.

For all species pooled, a stepwise logistic regression model involving 6 categorical and 5 continuous variables indicated a significant difference between nesting areas and random points for 5 variables. Nesting areas had more artificial structures, more vegetative cover, taller shrubs, and deeper soils than random points (Table 15). Nesting areas were also found in closed habitats more often than random points. The model was probably influenced by the many burrowing owls in the sample. A separate model for burrowing owls indicated that vegetation cover, shrub height, and soil depth were significantly greater at nesting areas than random points (Table 15). As with all species combined, burrowing owl nesting areas were in closed habitat types more often than random points. Sample sizes for other benchland species were too small for statistical analysis.

We found few significant differences in the relative availability of habitat features inside and

Table 15. Significant coefficients for a resource selection model fitted by stepwise logistic regression for breeding raptors on the benchlands.

Variable	Parameter Estimate	SE	Wald Chi-Square	P	Standard Estimate
All Species					
Intercept	-7.00	1.25	31.45	0.0001	—
Artificial Structures	2.85	1.19	5.69	0.0171	0.36
Veg. Cover Class	1.03	0.51	4.13	0.0420	0.23
Percent Veg. Cover	0.05	0.01	15.43	0.0001	0.47
Mean Shrub Height	0.02	0.01	4.93	0.0264	0.25
Soil Depth	1.11	0.25	20.41	0.0001	0.55
Burrowing Owls					
Intercept	-5.63	1.00	30.79	0.0001	—
Veg. Cover Class	3.56	1.11	10.26	0.0014	0.64
Percent Veg. Cover	0.05	0.01	17.60	0.0001	0.45
Mean Shrub Height	0.02	0.01	5.81	0.0160	0.24
Soil Depth	1.00	0.22	21.15	0.0001	0.49

outside the OTA. No random points inside the OTA were near agricultural developments compared to 13 random points outside the OTA (G_1 = 10.50, P = 0.001). Percent vegetative cover was higher inside the OTA than outside the OTA ($\bar{x}$ = 63.7, $\bar{x}$ = 54.5, t_{200} = 2.24, P = 0.02). Finally, the OTA had more rock outcrops (0.27 per random plot inside the OTA compared to 0.02 outside the OTA)(t_{200} = 2.00, P = 0.05).

Nest Distribution in the OTA.—In 1993, distances of occupied burrowing owl nests to major roads and firing ranges used in 1993 did not differ significantly from those at randomly selected points, (roads: $\bar{x}$ = 1,372 m, $\bar{x}$ = 1,794 m, t_{σ} = 0.91, P = 0.37; firing ranges: $\bar{x}$ = 4,059 m, $\bar{x}$ = 5,523 m, t_{σ} = 1.44, P = 0.16). Distances of successful burrowing owl pairs to bivouac sites, tank maneuver areas, tank tracking areas (military polygons), roads, and firing ranges were not significantly different than those of unsuccessful pairs (polygons: $\bar{x}$ = 1,438 m, $\bar{x}$ = 2,181, t_{15} = 0.46, P = 0.65; roads: $\bar{x}$ = 1,260 m, $\bar{x}$ = 1,141, t_{15} = 0.67, P = 0.51; firing ranges: $\bar{x}$ = 3,975 m, $\bar{x}$ = 4,941, t_{15} = 0.30, P = 0.77). Tendencies for successful and unsuccessful nests to be at similar distances to military activity centers were also observed when species were pooled (t-tests, P's > 0.32).

Though we detected no general effects of military activity on benchland raptors, we suspected military activity to be the cause of several nesting failures. A burrowing owl was observed at a burrow near Range 26 on 17 May, but the burrow was crushed by a tank later in the month. We had not confirmed that the nesting area was occupied by a pair prior to the destruction of the burrow, but burrowing owls were not seen there again. The burrow was on the shoulder of a cindered road about 0.8 km west of Range Road.

A second burrowing owl nest was destroyed by vehicle traffic near Christmas Mountain in the northern part of the OTA in mid-June. The nesting area was 25 m east of Pleasant Valley Road and within 200 m of a large bivouac site used during tank training maneuvers from mid-June through early July. Burrowing owls continued to be observed at adjacent burrows after the burrow had been destroyed, but no young were produced.

At Flagstaff Butte, extensive tank training exercises occurred in late June within 100 m of a burrowing owl nesting area that had been occupied by a pair since late March. A single burrowing owl was observed at the burrow on 1 July and at an adjacent burrow on 6 July, but no adults or young were observed in spite of 2 additional nest checks in late July.

In contrast, 2 burrowing owl pairs nested successfully down range and within 1 km of Range 6, which was used frequently during late May and throughout June. One of these pairs was only 600 m from the firing pad at Range 6. Also, a northern harrier pair bred successfully in the northeastern corner of the OTA, though the nest was inside the boundary of a large (>3 km^2) tank maneuver area used extensively from 15 May to 5 June. A single fledgling was observed in the area on 23 June.

DISCUSSION

Prairie Falcon Abundance and Reproduction

Changes since the 1970's.—Between 1990 and 1993, numbers of prairie falcon pairs in the SRBOPA have been within the range of pair numbers observed between 1976 and 1978. This suggests that there has been no marked decrease in overall nesting population size during the past 17 years. Within the ISA, most 10-km stretches have had relatively stable numbers of nesting pairs. East of the ISA, Unit 15 has had pair numbers consistently below 1976-78 levels since 1990. Prairie falcons east of the ISA also have had lower densities, occupancy rates, and reproductive success during the past 3 years than pairs in the ISA. This area had lower ground squirrel densities than the ISA in the 1970's and may be lower quality prairie falcon habitat (U.S. Dep. Inter. 1979). Permanent changes (e.g., fires, agricultural development) east of the ISA may have made some areas less suitable for ground squirrels and therefore prairie falcons.

OTA Effects.—This was the first year that prairie falcon nesting success was significantly lower within the OTA shadow than immediately east and west of the shadow. Productivity of control pairs throughout the SRBOPA was lower in 1993 than in any year since 1982, suggesting that 1993 was a stressful year for prairie falcons. Lowered success rates and number of young fledged per attempt may have been related to reduced ground squirrel abundance (Van Horne et al., this

volume), unusually wet spring weather conditions, or a combination of these and other factors. The effects of these factors on nesting success appeared more marked in the OTA shadow for unknown reasons. Successful pairs in the OTA shadow produced similar numbers of young that had similar weights as those east and west of the shadow. In 1993 radioed prairie falcon pairs had markedly, but not significantly, lower success rates than control pairs. Because this pattern was not observed from 1990 to 1992, we suspect that radios may have more of an effect on falcon productivity when falcons are stressed by other factors.

Golden Eagle Abundance and Reproduction

Changes in Abundance.—The number of occupied golden eagle nesting areas in the SRBOPA has declined significantly since the late 1970's. Although no more than 35 of the 36 historic territories identified by 1974 were occupied in any given year, only 28 of them were occupied in 1993. Some of these territories have been vacant for ≥ 11 years and may be permanently lost. Although there has been a loss of some territories, 3 were newly established in last decade on the PP&L 500-kV transmission line. Although PP&L 102 and PP&L 125 were occupied for only 1 year, the PP&L 119 territory has been occupied every year since it was established in 1983.

Reproduction.—Golden eagle reproduction has varied greatly since surveys began in 1971, but long-term productivity appears stable. In the SRBOPA the average number of young fledged per pair since 1980 (0.84) was slightly higher than that recorded in the 1970's (0.73) and was similar to the 22-year average since 1971 (0.81). Long-term productivity in the SRBOPA was not appreciably lower than that of the Comparison Area (Table 7).

Fluctuations in eagle productivity can be attributed primarily to cyclic jackrabbit abundance and secondarily to weather (Kochert and Steenhof unpubl. data). Golden eagle productivity appears closely linked to jackrabbit abundance prior to the breeding season, but winter severity may influence eagle productivity when jackrabbit abundance is low. Although the number of occupied nesting areas in the SRBOPA has decreased, eagle productivity in 1993 was exceptionally high, and the estimated total number of young produced was the highest since 1982 (Table 6). This may have been influenced by both a mild winter prior to the 1993 season and cool spring of 1993. In 1994 we will assess the relationship between eagle reproductive performance and jackrabbit abundance and the influence of weather in greater detail.

Golden Eagles and Wildfires.—Lehman et al. (1992) suggested 2 possible causes for the decline in golden eagle numbers: loss of foraging habitats by wildfires since 1980 and agricultural development during the late 1960's and early 1970's. Wildfires in the SRBOPA have converted much of the native shrub-steppe vegetation to open grassland composed primarily of cheatgrass (*Bromus tectorum*) and other exotic species (Yensen 1982). Smith and Nydegger (1985) found lower densities of black-tailed jackrabbit (*Lepus californicus*) in burned grasslands in the SRBOPA, and U.S. Dep. Inter. (1979) reported that agricultural areas did not support jackrabbit populations. These observations suggest that the loss of native vegetation due to burning and agriculture has reduced jackrabbit numbers within golden eagle foraging habitat.

Our preliminary analyses suggest that most eagle territories that became vacant in the 1980's, and remained so, were associated with high amounts of burns or agriculture. This relationship is strengthened by the fact that all territories that appear to be permanently lost are associated with high amounts of either burns or agriculture, and most of the territories that failed to produce young in >75% of the years since 1980 were also associated with large amounts of burned area.

The relationship between eagle occupancy and success and wildfire must be analyzed in greater detail in 1994. We need to examine the habitat components of each territory using GIS vegetation maps of pre-1980 and post-1980 vegetation relating this to the individual histories of each territory. Because of variability in range sizes among eagle pairs in the SRBOPA (Marzluff et al., this volume), we need to examine habitat components using concentric contours around the nesting areas based on the information from Study 2 instead of a fixed radius.

Nesting of Raptors on the Benchlands

Relative Abundance.—In 1990, we found only 4 raptor nests during a limited pilot effort to assess

raptor nesting abundance on the benchlands. At the time, we concluded that abundance of nesting raptors on the bench was low. Since 1990, numbers of pairs found on the bench have increased steadily as survey efforts have increased; from 64 pairs in 1991 to 94 in 1992, and to 106 in 1993 (see Lehman et al. 1990, 1992 and Steenhof et al. 1991 for a description of methods).

Survey results since 1991 indicate that nesting raptors on the benchlands are more abundant than we concluded in 1990. However, the number of pairs found during random plot surveys (quadrats, line transects, and variable circular plots), has been very low (15 in 1991, 16 in 1992, and 23 in 1993). Small sample sizes at random plots have hindered statistical comparisons of relative abundance inside and outside the OTA, but have allowed comparisons inside quadrats on a unit area basis. In 1992 we found 0.29 pairs per quadrat inside the OTA compared to 0.40 pairs per quadrat outside the OTA; in 1993, nesting densities inside and outside the OTA were 0.45 and 0.48 pairs per quadrat, respectively. These data suggest that relative abundance of nesting raptors is low throughout the ISA. Pooling data from different survey methods also suggest low densities. In 1992, we found 3.9 pairs per 100 km^2 inside the OTA (all methods combined) compared to 5.0 pairs per 100 km^2 outside the OTA. Estimated densities inside and outside the OTA in 1993 were 4.4 pairs per 100 km^2 and 5.6 pairs per 100 km^2, respectively.

In 1993, we found only 11 pairs of short-eared owls, compared to 24 pairs in 1992 and 18 pairs in 1991. Yet, survey efforts for short-eared owls were comparatively greater because of a radiotelemetry study that began this year in the SRBOPA (see Rivest, this volume). In spite of increased efforts, breeding was confirmed at only 3 nesting areas, and fate was confirmed at only 2 nesting areas. Lower numbers of short-eared owls and breeding pairs in 1993 may reflect a cyclic population decline, or emigration of short-eared owls from the SRBOPA. Some short-eared owl populations, especially those dependent on voles (*Microtus* spp.), are synchronized with prey cycles (e.g., Korpimäki 1984). Other populations are nomadic and move between areas with irruptive prey increases (Clark 1975). Yearly monitoring of short-eared owls will be necessary to better understand the species' population dynamics in the SRBOPA.

We believe random sampling and other survey efforts on the bench should continue at least for the duration of the BLM/IDARNG study. Though sample sizes may continue to be low, random sampling offers the least biased approach to comparing relative abundance of raptors in areas exposed to military activity with unexposed areas. To facilitate between-year comparisons, we believe that quadrat surveys should continue as the approach to random sampling. Monitoring of historical and incidental nesting areas should continue to allow assessment of overall numbers and, when possible, nesting success of raptors on the bench.

Nesting Success.—As in previous years, our attempts to compare nesting success of most benchland raptors inside and outside the OTA were limited by small sample sizes. We were able to confirm breeding during incubation and nesting success at most ferruginous hawk and northern harrier nesting areas, but the number of pairs found was too low for statistical analysis. This may reflect naturally low numbers of both species on the benchlands. We would not expect sample sizes for these species to increase significantly even if we increased survey efforts.

In 1992, we suspected burrowing owl pairs that failed early in the breeding period were missed and felt the species' success rate (90.9%) was biased towards successful pairs. In 1993, we began burrowing owl surveys earlier than in 1992 and concentrated search efforts for burrowing owls at dawn and dusk. Also, we analyzed nesting success for pairs found before the median hatch date rather than the earliest hatch date to increase our sample of nesting areas found during incubation. As a result, our sample of burrowing owls found during incubation increased between 1992 and 1993 from 55.0% to 73.0% of all nesting areas where fate was determined. In 1993, the overall success rate for burrowing owls in the ISA dropped from 90.9% to 39.1%. This decline probably reflects both a more accurate assessment of nesting success in 1993 as well as an actual drop in nesting success. Heavier-than-normal rains in the spring and early summer of 1993 may have contributed to a higher failure rate. Declines in nesting success between the 2 years were about the same inside and outside the OTA: success dropped from 83.3% to 33.3% inside the OTA and from 93.8% to 42.1% outside the OTA.

Habitat Assessments.—A variety of habitat features were useful in discriminating between occupied nests and random points, and between successful and unsuccessful nesting areas, but the relative occurrence of most habitat features inside and outside the OTA did not differ. Habitat assessments allowed us to describe apparent species preferences for different habitat features, and may allow refinement of survey efforts in the future. Ferruginous hawks occurred most often in areas with good vegetative cover, where artificial perches and nest structures were available near rock outcrops. Burrowing owls also "preferred" areas with good vegetative cover and perch availability, but occurred more in flat areas and deeper soil sites than other species.

Mean shrub cover tended to be low for all species, but was higher than at random points at northern harrier and short-eared owl nesting areas. Mean shrub height was also greater at short-eared owl nesting areas than at random points, and short-eared owls were found more often than other species in "closed" habitat types. These data suggest that northern harriers, and especially short-eared owls, prefer shrubbier areas that allow cryptic placement of nests.

Nest Distribution in the OTA.—We detected no significant differences in the location of burrowing owl nests and random points relative to military activity centers. However, intensive field activity by IDARNG did not begin until mid-May, well after most breeding owls had established nesting areas and laid eggs. Nor did we detect significant differences in the location of successful and unsuccessful burrowing owl nests relative to military activity. However, the number of burrowing owls in the OTA for which fate was determined was low ($n = 18$). Given that densities of all nesting raptors in the OTA tend to be low, and military activities tend to be localized and dispersed (N. Nydegger, Idaho Army National Guard, pers. commun.), we doubt that military activity in general plays an important role in the fate of nesting attempts in the OTA. However, local impacts to particular pairs were documented.

PLANS FOR NEXT YEAR

In 1994, we will continue surveys of prairie falcon, golden eagle, and ferruginous hawk abundance and productivity in the canyon and quadrat surveys on the benchlands. We will assess occupancy and nesting success again at historical benchland nesting areas, assess habitat characteristics at occupied nesting areas and random points, and relate raptor nesting distribution in the OTA to military activities. In 1994, we hope to determine nesting success at burrowing owl nesting areas by observing owls at night with night vision equipment, and possibly by observing owls in their burrows with the use of fiber optical or related systems. We may also attempt to trap owls at their burrows to increase detection rates of fledging-aged owls. In 1994, we will use a combination of burn maps and 1992 vegetation maps, rather than burn maps alone, to assess relationships between golden eagle and ferruginous hawk reproduction and wildfires. Finally, we will continue the radio telemetry study of short-eared owls, but in 1994 will radio adults as well as nestlings. We are also considering a food habits study and a study of small mammal populations at short-eared owl nesting areas to assess relationships between food availability and reproductive success.

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Influence of Military Training on the Behavior of Raptors in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*We assessed the potential influences of military training on the ranging and foraging behavior of 35 radio-tagged prairie falcons (**Falco mexicanus**), 9 radio-tagged territorial golden eagles (**Aquila chrysaetos**), 5 radio-tagged wintering golden eagles, and all raptors utilizing firing ranges in the Orchard Training Area (OTA) in 1993. Many results were different from those reported in 1991 and 1992. In particular, breeding prairie falcons foraged over larger areas, exhibited a more even distribution in the use of prey items, spent less time in their territories, delivered fewer prey items to their older nestlings, dispersed from the study area sooner, and rarely bred successfully. Golden eagles also exhibited a more even use of prey items, made fewer hunting attempts, and bred less successfully in 1993 than in 1992. We interpret these changes in behavior as reflections of significantly lower populations of these species' primary prey, Townsend's ground squirrels (**Spermophilus townsendii**) and black-tailed jackrabbits (**Lepus californicus**).*

The effects of military training on raptor abundance and behavior were influenced by the annual variations in prey availability. Avoidance of areas with live firing was seen in all 3 years, and the added travel requirements such avoidance imposed upon falcons nesting in the OTA shadow may have been part of the reason that these birds were especially unproductive in 1993. However, distances traveled increased significantly for falcons utilizing areas exposed to training and for those utilizing areas rarely exposed to training. This suggests that prey availability was the principal factor affecting falcon behavior. Therefore, the consistent observation that foraging ranges of falcons were larger in the OTA shadow than west of the shadow has more likely been due to the difference in prey availability brought on by environmental differences (some anthropogenic, others climatic or geologic) between the OTA shadow and the western area than to the short-term effects of live-fire training. Likewise, these environmental differences were probably more responsible for the reduced productivity of OTA shadow birds. Differences in productivity and ranging habits were accentuated in a poor prey year like 1993 to the point of influencing fecundity because falcons using a typically impoverished prey base cannot range far enough to find enough prey to feed nestlings.

*Golden eagle ranging habits were extremely individualistic, but eagles with home ranges that contained small amounts of medium and high density sagebrush (**Artemisia tridentata**) tended to be larger than those with home ranges that contained large amounts of this preferred foraging habitat. Territories continued to be large (930 - 55,407 ha) relative to previous studies because we observed eagles taking long excursions from the nest area. Non-resident adult golden eagles wintering in the OTA consistently used particular areas within the OTA and left the study area during late March and early April, returning to presumed breeding locations in central and southeastern Alaska/northwestern British Columbia. The more nomadic subadults included the OTA in their wintering ranges, but ranged farther than wintering adults and did not leave this range during the breeding season.*

OBJECTIVES:

1. Assess the impacts of backpack radio transmitters on the behavior and productivity of prairie falcons and golden eagles.
2. Determine the spatial use patterns of prairie falcons in the Orchard Training Area (OTA) shadow and west of the shadow.
3. Assess the impacts of military training on the ranging habits, nesting behavior, and productivity of prairie falcons.
4. Assess the impacts of military training on the abundance and behavior of raptors utilizing firing ranges in the OTA.
5. Monitor habitat use of resident, adult golden eagles.
6. Monitor habitat use of golden eagles wintering in the OTA.

INTRODUCTION

Study 2 is responsible for assessing the potential influences of military training on the behavior of raptors nesting in the Snake River Birds of Prey Area (SRBOPA). 1993 represents the third year of intensive research designed to understand if, and how, this training influences the spatial use patterns, foraging behavior, and parental care exhibited by raptors.

Our research has 3 main components: (1) We focus on the most abundant and farthest ranging raptor breeding in the SRBOPA, the prairie falcon, to assess the effects of military training throughout the study area; (2) At the sites of actual military training (firing ranges, bivouac areas, driving areas, and construction sites), we quantify the responses of all raptors to human activity; and (3) We investigate the ranging habits of territorial and wintering golden eagles to assess their habitat requirements.

The objective of this report is to present the results from the 1993 season and, more importantly, to compare and contrast them with results from 1991 and 1992. The variable nature of the Great Basin Desert environment was strikingly evident in comparing this year to previous years: populations of principal prey species (black-tailed jackrabbit and Townsend's ground squirrel populations were very low [Knick, this volume, Van Horne, this volume]), and temperatures during the summer were the coldest on record (National Weather Service, Boise, ID).

METHODS

Terminology

We use the following terms to reference the space used by prairie falcons in the Snake River Canyon: a *nesting area* is a stretch of cliff where nests are found year after year, but no more than 1 pair has ever bred at 1 time; a *territory* is defined as the cliff and canyon terrain actively defended by a pair in a given year; an *aerie*, *scrape*, or *nest* refers to the actual nest location.

The definitions of the OTA shadow, areas west of the shadow, and areas east of the shadow remain as stated in Marzluff et al. (1992).

Trapping Prairie Falcons

We investigated 86 historical nesting areas for the possibility of trapping prairie falcons in 1993 (45 were from the Study 2 OTA shadow pre-selected list, 30 were from the Study 2 west of OTA shadow list, and 11 were from the Study 2 east of OTA shadow list). We rejected 51 sites because adults were not present or not exhibiting territorial behavior (n = 31), because other raptors–primarily ferruginous hawks (*Buteo regalis*)–were nesting nearby (n = 2), or because the adults were not responsive to the trapping methods attempted (n = 18). We set traps during courtship, egg-laying, and incubation in 59 historical nesting areas, and captured a total of 40 adult prairie falcons in 39 nesting areas during March, April, and May 1993.

Nesting areas selected for trapping were a random sample of all areas previously stratified into 3 categories: those within the OTA shadow, those west of the OTA shadow, and those east of the OTA shadow. Seventeen captures occurred west of the OTA, 17 occurred in the OTA shadow, and 6 occurred east of the OTA shadow. We placed a radio transmitter (14 - 16 g) on each captured falcon unless eggs were felt in the abdomen or the individual had been instrumented in a previous year of the study. We placed radio transmitters on 16 birds in the OTA shadow (1 individual shed its transmitter soon after the trapping period, the site was retrapped, and the mate of the individual was captured), 15 birds west of the OTA shadow, and 5 east of the OTA shadow.

Two teams trapped from 16 March through 1 May 1993, with an additional trapping day on 19 May 1993 to replace the shed radio. Methods for capturing, measuring, applying radio transmitter backpack packages, and monitoring prairie falcons were described in Marzluff et al. (1991) and modified in Marzluff et al. (1992). One modification was made to the harness configuration this year: copper tubing segments were crimped around the Teflon® where it emerged from the posterior tubes of the transmitter. This reduced the average handling time from 79 min (n = 32, SD = 23) to 63 min (n = 35, SD = 10). Cotton knots were used on the anterior end of the transmitter as described in Marzluff et al. (1992). Birds were released as soon as the attachment was completed. Band combinations and physical characteristics of all falcons captured through May 1993 are listed in Appendix A.

Productivity

Field Protocol.—We monitored the breeding status of 31 pairs of prairie falcons (13 west of the OTA shadow, 15 in the OTA shadow, and 3 east of the OTA shadow) that included a radio-tagged adult. We could not determine the breeding status of 4 radio-tagged falcons (2 west of shadow and 2 east of shadow) that were not observed regularly within any historical nesting area. We observed aeries to determine nestling age and rappelled to aeries to measure nestlings as described in Marzluff et al. (1991). All nestlings were accounted for at successful aeries. We monitored unsuccessful aeries as described in Marzluff et al. (1991). Study 3 monitored the breeding status of 47 pairs of prairie falcons (12 west, 19 shadow, and 16 east) without radio-tagged adults (Lehman et al., this volume). Study 3 monitored 4 additional pairs of falcons but dropped them from the control sample because 1 member of each pair still carried a transmitter from a previous year.

Analysis.—We tested the null hypothesis that radio transmitters had no effect on the probability of a pair fledging young, on the weight of young, or on the frequencies of adult activities (prey deliveries to young, attendance at the nest or attendance in the territory). The distribution of successful and failed nesting attempts was compared between instrumented and control pairs using a Likelihood ratio Chi-squared test. We used a heterogeneity test to determine if data from separate years could be pooled for this analysis. We compared weights between nestlings of instrumented and control pairs using an ANOVA with length of seventh primary, brood size, and footpad as covariates. We placed nestlings into 2 mutually exclusive groups based on footpad length: small nestlings (presumably male) with footpads <86 mm and large nestlings (presumably female) with footpads >86 mm. We also adjusted nestling weights for crop fullness (BLM, unpubl. data). In 1991 and 1992, the individual nestling weight was treated as the sampling unit, but in 1993, we conducted separate analyses using individual nestling weights and the mean weight of all same-sex nestlings in a nest as the sampling unit, and re-analyzed the 1991 and 1992 data in this manner. We examined the interaction between year and radio-tagging on nestling weight using a 2-factor ANOVA on the pooled data, with seventh primary, footpad, and brood size as covariates. The numbers of

fledglings per nest and fledglings per successful nest were compared between instrumented and control pairs using ANOVAs; we also tested for an interaction between year and radio-tagging on fledgling numbers with a 2-factor ANOVA on the pooled numbers of fledglings per nest and numbers of fledglings per successful nests. Adult activities, grouped by sex, were compared between instrumented falcons and non-instrumented falcons with radio-tagged mates, using ANOVAs with brood size and hatch date as covariates; results from 1991 and 1992 were re-analyzed using these covariates. We examined the interaction of year and radio-tagging using 2-factor ANOVAs on the pooled frequencies of activity of instrumented and non-instrumented falcons, again with brood size and hatch date as covariates.

Radio Telemetry

Field Protocol.—We tested our ability to locate stationary beacons in the study area while tracking from the 10 tracking zones established in 1992. These beacon tests indicated that coverage of the OTA and the Integrated Study Area (ISA) west of the OTA was complete (Fig. 1). Therefore, use of the zones remained the same as in 1992, as did the use of 6-person tracking teams (Marzluff et al. 1992). Radio-tracking team members were trained from 15 - 19 March. New trackers were trained as they arrived throughout the season. Each person became familiar with the equipment, receiver sites, and protocol by estimating the location of stationary and mobile beacons and instrumented falcons before intensive radio-tracking commenced.

We randomly selected both the tracking zone and whether the zone was to be sampled in the morning or evening on a given day. Morning tracking started within 1 hr of sunrise while evening tracking started at approximately 1200-1400 hr. It took 20 days to cycle through 1 morning and 1 evening session in each zone. Unlike in 1992, we did not supplement tracking in high use zones in 1993. The number of days sampled per zone was: Zone OTA1 = 8, OTA2 = 9, W1 = 12, W2 = 12, W3 = 10, W4 = 10, W5 = 8, W6 = 12 (see Marzluff et al. 1992, Fig. 1). Tracking sessions lasted for 7 hrs. unless interrupted by inclement weather or equipment failure.

Each member of the tracking team was positioned at 1 of the 6 receiver sites within each zone. Trackers used 4-element Yagi antennas and programmable scanning ATS receivers to sequentially sample for radio frequencies of instrumented falcons. Towers with compass rosettes were used by all trackers in 1993. Tower height was 2 m on naturally-elevated sites such as buttes, and 5 m on lower sites. A hole in the rosette base was preset to north; a corresponding hole drilled in the rosette enabled trackers to automatically and consistently orient the rosette by bolting the rosette to the base. Trackers used 2-way radios to alert other team members to the presence of a falcon in the sampling area. When 2 or more trackers received the falcon's signal, a coordinator called for a simultaneous bearing to be taken as described in Marzluff et al. (1991). As in 1991 and 1992, we allowed ≥30 min between successive fixes on the same bird. Thirty min was sufficient time for a falcon to traverse the study area and spread our sampling effort throughout the field season, assuring that our sample of fixes was representative of the falcons' use of the study area (White and Garrott 1990). However, we also took fixes on some birds <30 min apart for use in autocorrelation analyses.

We continued to monitor falcon use of the study area until all birds dispersed. Most birds were no longer in the study area after late July, but we sent a single observer to prominent high points to scan for birds. Observers scanned from 0800 - 1400 hr (2 hrs per site, sites visited in random order) and then drove in search of falcons to determine if radios had been shed and/or to obtain visual observations of the few remaining birds.

Weather data were obtained from a portable weather station placed at 1 of the tracking sites each day. Types of weather data collected were described in Marzluff et al. (1992).

Direct Observations of Prairie Falcons.—To assess our ability to estimate location and habitat use of prairie falcons by remote radio-telemetry, we visually monitored 8 radio-tagged male falcons. We monitored 4 individuals in the OTA shadow (Tom Butte West, Jackass NW, Black Butte I, Balls Point Face), and 4 individuals west of the OTA shadow (Priest Upper, Ogden Rock Upstream, Priest IV, and Falcon Flats Cave) during 20 tracking sessions from 7 May - 13 July. All monitoring sessions were undertaken from the north side of the river by 2 observers in 1 vehicle. Target falcons were radio tracked until visual contact was established and then followed until they were lost from sight. Visual observations

Fig. 1. Location of test beacons that could be received from tracking positions with respect to the ISA (solid line), OTA (shaded line), and Range Road (dashed line)

were scheduled to coincide with remote tracking sessions of the target falcons. For analysis, visual observations were divided into 2 categories based on accuracy of location: "known" for when falcons were perched on a physical object with an accurately determined location, and "estimated" for when the falcon was flying and its location was determined with less precision.

Analyses.—In previous years we used Lenth's (1981) Maximum Likelihood Estimator (MLE) to determine an error ellipse around each fix. After analysis of linear error using beacon data, we determined that MLE used with a multiple regression model incorporating error polygon shape and size better estimated transmitter location. Therefore, our classification of acceptable fixes will likely change after 1993, although in this report we present data using error ellipses <1000 ha as a selection criterion for comparisons with previous years' data. Accuracy of fixes was also tested against visual observations of prairie falcons. The linear error from the estimated fix location and the visually-determined location was used to test the effectiveness of the multiple regression model.

In 1993, most nesting attempts were unsuccessful, but we did not always know if unsuccessful falcons ever attempted to nest (i.e., laid eggs). We therefore used 3 categories for nest-based analyses: (1) "unsuccessful pairs" were pairs that consistently were found in a traditional nesting area that were known not to have fledged young; (2) "non-breeders" were pairs that could not be found attending a traditional nesting area; and (3) "successful pairs" were pairs known to have fledged young. Unsuccessful pairs and non-breeders were often lumped for comparison with successful pairs. We treated unsuccessful pairs as "successful" pairs in all analyses based on nesting success until they failed, at which time they became "unsuccessful pairs". Otherwise, analyses of home ranges were the same as in 1992 (Marzluff et al. 1992) using Kenward's (1993) RANGES program. Whenever possible in this report, analyses were done using year as a variable to test for differences among years, and to test for interactions of year with other variables.

Analyses of contact rates and travel distances from the aerie are as described in Marzluff et al. (1992). To more precisely test the effect of military training on falcon travel distances, we split the area inside Range Road into 2 sections: the northern portion of the OTA that included ranges 1 - 6, 10, and 11, and the southern portion that included ranges 14, 15, 20, 22, 26, and 30. If any range was firing in a section, the entire section was considered to be "firing". If no ranges were firing, the section was considered to be "not firing". This allowed us to identify whether the area inside Range Road area was firing (both north and south sections containing ≥1 firing ranges), just 1 section was firing, or the entire area was not firing (neither section has a range firing). In addition, the distance of each fix from each range was calculated, and the firing status of the range determined at the time of the fix. We used this information to determine whether a falcon was closer to a firing range or to a non-firing range.

Habitat Use.—We selected points for assessment of habitat use on the basis of their estimated linear error. This model was based on beacon data and tested against a group of independent visual observations of falcons. Fixes with an estimated linear error of <2,500 m were used to produce a 95% harmonic mean range. We used the ARC/INFO Geographical Information System (GIS) to overlay these home ranges on the habitat map produced by Knick et al. (this volume) and determined the amount of available habitat within each falcon's range. We selected a subset of points in each home range that had linear errors <1,500 m to assess the habitat used by falcons. A circle a with radius of 1,500 m was centered at each of these fixes and the amount of each habitat within these circles was compared to the amount available to determine selectivity or avoidance for habitat types.

Behavior of Prairie Falcons in Territories

Field Protocol.—We monitored 14 of the 35 instrumented falcons and 5 non-instrumented falcons in their territories from 4 May - 28 June 1993 to determine parental attendance and prey delivery rates (Table 1). The territories with non-instrumented adults were added as replacements for territories that failed during the breeding season. Seven of the territories were within the OTA shadow, and 12 were west of the OTA (Table 1). We watched each territory for an average of 47.8 hrs (range = 14.8 - 95.0 hr) over an average of 3.1 days (range = 1 - 6 days) from blinds placed to optimize our view of the scrape and minimize disturbance (distance from blind to aeries = 150 m, range = 80 - 300 m; following Holthuijzen 1990). All scrapes were viewed from below nest

Table 1. Prairie falcon territories, in the OTA shadow and west of the OTA, where prey delivery observations were conducted in 1993. The stage of the breeding cycle when observations were made is marked (x). An * indicates that the territory was attended by an instrumented adult.

	BREEDING CYCLE			
Territory	Incubation	Early Brood Rearing	Late Brood Rearing	Post-Fledging
OTA SHADOW NESTS				
Black Butte I *	x			
Carlsbad *	x			
CSJ Jr			x	x
Jackass NW *		x	x	x
Henderson Draw *	x			
Swan I Draw	x			
Tom Butte West *	x			
WEST OF OTA SHADOW NESTS				
Camera				x
Cattleguard Gate *		x	x	x
Corral Downstream *		x		
Falcon Flats Cave *		x		
Fang *		x	x	x
Hell Hole Peregrine *		x		
Priest Rapids I *		x		
Priest IV *	x	x		
Priest Upper *		x	x	x
Swan Dam Draw			x	x
Swan Dam Three Poles				x
Wolf Draw *		x	x	

level although at 3 sites we were able to see fairly well into stick nests. Blinds were set up for the entire field season at all territories except for 7 sites west of the OTA (Camera, Cattleguard Gate, Corral Downstream, Fang, Hell Hole Peregrine, Swan Dam Draw, and Swan Dam Three Poles) and 2 sites in the OTA shadow (CSJ Jr and Swan I Draw) where we used a truck (sitting inside or next to it) or a portable blind.

As in 1991 and 1992, we maximized the number of territories observed rather than the number of days each territory was observed. Because of the high failure rate at nests in 1993, not all nests were watched during the entire brood-rearing period. Only 5 nests were observed during both the early brood-rearing (nestlings <21 days old) and late brood-rearing periods (nestlings 21 - 40 days old; Table 1). In total, we completed 58 full days of observation. As in previous years, our observation schedule was not randomized because of logistical constraints (territories close to each other were observed during the same week) and military training schedules (territories in the OTA shadow were observed on firing and non-firing days).

Ten observers, divided into 2 groups, conducted all behavioral observations. One group observed the OTA shadow territories, and the other group observed the territories west of the OTA. Differences between observers were minimized by training which included 1 day of indoor instruction and 1 day of observing prairie falcons at an aerie while recording behavioral data. Observers further sharpened their skills by watching falcon pairs and locating their scrapes. Late in the season, OTA shadow observers watched aeries west of the OTA because of nest failures in the OTA shadow. Data collected included parents' time budgets and prey handling activities, and weather conditions, as described in Marzluff et al. (1991, 1992). Laptop computers were not used in 1993.

Analyses.—The high number of nest failures in 1993 resulted in few nests for which we obtained behavioral observations throughout the entire brood-rearing period. As a result, small samples precluded the use of repeated measures ANOVAs for the 1993 data; only the means of parental behaviors are reported. However, 1993 data were pooled with data from previous years when appropriate. Prior to pooling, we tested for year effects with a repeated measures ANOVA with 2 factors: OTA (nesting areas in the OTA shadow versus west of the OTA) and year (1991, 1992, and 1993) and 2 repeated measures (age of young and sex of parent). If the main effects of year and the interactions between year and the other factors were not significant, then we interpreted the effects of OTA, age of young, and sex of parent in the analysis of pooled data. For all analyses, multiple observations of behavior within the early and late brood-rearing periods were averaged to increase the normality of the response variables. Percentages were transformed (arcsine of their square root) prior to analysis.

We used correlation analysis to test for the effects of brood size and hatch date on our measures of parental attendance and prey delivery rate. We also used these 2 variables as covariates in the repeated measures ANOVAs described above.

The influence of nestling age was further investigated by using each day of observation as an independent sample. We then correlated a daily average value for each behavior with the estimated average age of the nestlings. The probability associated with these correlations may be inflated because repeated daily observations at the same nest are not independent.

Sample sizes for paired observations of parental behavior on military training and non-training days were small for 1991, 1992, and 1993. Therefore, all data were pooled to test for military training effects. We sampled behavior of falcons nesting within the OTA shadow on 14 pairs of days and those nesting west of the OTA on 9 pairs of days (within 1 - 5 days of each other); 1 day in each pair was a day when training occurred on the OTA ranges, and the other day was a day when training did not occur. Average behavior on training versus non-training days was compared with a repeated measures ANOVA using nestling age as a covariate. The model had 1 repeated measures factor (training versus non-training).

Behavior and Abundance of Raptors on the Orchard Training Area

Field Protocol.—We monitored the abundance and behavior of raptors on 8 firing ranges, 4 bivouac/maintenance areas, 1 construction area, and 6 maneuver areas for a total of 749 hrs (89 observer days) during April, May, June, July, and August 1993. The ranges were located inside the circular cinder Range Road and extended toward an artillery impact area (Fig. 2). The bivouac/maintenance areas were located both inside and outside of Range Road. Our study areas on ranges were described in Marzluff et al. (1991) and included 5 tank training ranges (ranges 1, 5, 10, 11), 1 small arms firing range (range 14), 1 missile range (range 26), and 2 ranges utilized for a variety of firing activities (ranges 3, 6). Scanning procedures at firing ranges, behaviors recorded, and military activity categories were described in Marzluff et al. (1991), and scanning procedures for bivouac/maintenance study areas were described in Marzluff et al. (1992). The standard observation period at firing ranges, bivouac/maintenance sites, and the construction site began at 0700 hr and continued until 1500 hr (MST). We sampled 1 range 6 times from 0700 hr until dusk (approximately 2040 hr).

In 1993, we examined the influence of military training exercises outside of Range Road on raptor abundance and behavior. We surveyed tank maneuver areas (MA) using point counts (Fig. 2). Eight observation points (OP) were positioned around the boundary of each MA. Observers stopped at each OP to survey inside of the MA using binoculars and variable power spotting scopes. The left and right scan limits were the MA boundary lines on either side of the OP. At each OP, the military activity (seen or heard) and all observations of raptors were recorded and their locations plotted on a map of the MA. For each raptor observed, we recorded the time of observation, species, distance and angle to the raptor, and a 1-min string of behaviors. Observers scanned from each OP for 15 min before moving on to the next OP. Observations began at the first OP along the transect at 0700 hr (MST), and observations at subsequent OPs began on each half hour thereafter (resulting in observations made from each OP once in the morning and once in the afternoon). All raptors observed were monitored peripherally throughout the observation period at each OP to avoid recounting individuals during a scan.

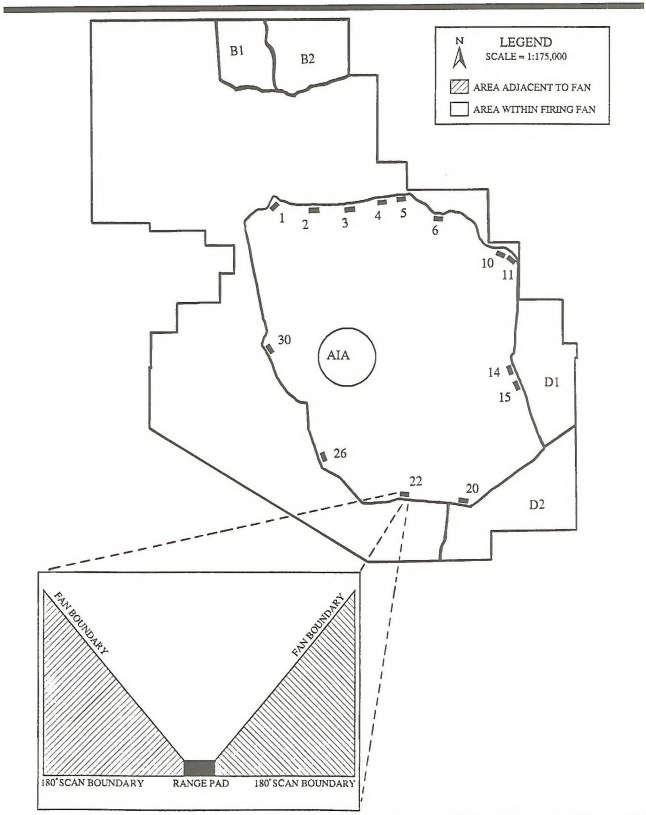


Fig. 2. Military training ranges (numbers) and maneuver areas (B1, B2, D1, D2) where observations were conducted and detail of 1 sampling area. Firing fans and adjacent areas are centered on the firing pad at each range and the entire 180- degree area is scanned. Scans on the maneuver area are bounded by the borders of the maneuver area.

Each range, bivouac/maintenance area, and maneuver area was sampled on days that the activity was taking place (hereafter referred to as *active, training* or *firing* days) and again on days when no activity occurred (*inactive, non-training* or *non-firing* days). Each daily survey of raptor and military activity was conducted by a single observer. Throughout the course of our study, 5 individuals acted as observers on ranges and bivouac/maintenance areas, and 8 individuals observed maneuver areas. Three of the observers surveyed ranges during the 1991, 1992, and 1993 study seasons; 1 other observer surveyed ranges during the 1992 and 1993 seasons. Each individual surveyed most ranges at least once on a training day and once on a non-training day.

From June through August 1993, the National Guard constructed a 75-ha series of cindered pads connected by 2, 6.1-m wide cinder roads. We observed the construction area 3 times prior to the start of construction, and 6 times during the construction (on 4 days when construction was taking place and 2 days when there was no construction or firing activity on the OTA). Scanning procedures were the same as those done on ranges, with 2 exceptions: the location of each raptor observed was plotted on a 1:24,000 topographical map and the "in fan" area was defined as the area most heavily impacted by the construction activity (bordered by Pleasant Valley Road on the north, Range Road on the east, and the road under construction on the south and west).

Analyses.—Military use of ranges was categorized more specifically in 1993 than in previous years. In 1991 and 1992, we grouped data into firing and non-firing days based on whether there was any firing on the OTA on the day of observation (regardless of whether the range we were observing was being used for training). To better understand local effects of training, in 1993 we only used observations from ranges upon which firing took place on the day of observation. We then re-analyzed the 1991 and 1992 data using these criteria. We obtained an average number of raptors observed in maneuver areas in the morning (0700 - 1100 hr) and in the afternoon (1100 - 1500 hr) and compared the numbers of birds observed in the morning and in the afternoon using a 2-factor, repeated measures ANOVA; time of day was crossed within activity of the range (active or inactive). The number of days from 1 January 1993 until the day of observation was used as a covariate in this analysis to adjust for seasonal changes in raptor abundance. We obtained range-use data for 1991-93 from the Idaho National Guard and compared daily counts of men and vehicles to the average number of raptors observed per hour on the ranges to determine if there was a correlation between numbers of raptors using the ranges and the level of activity on the OTA. In all analyses of multiple years of data, we investigated whether raptor abundance or behavior differed between years. We again expanded our analysis of hunting behavior on the ranges (Marzluff et al. 1992) by including the number of attacks observed during 1993 in the analyses. Marzluff et al. (1991) described the remaining analyses performed.

Golden Eagles

Trapping and Observations.—We selected 2 additional territories for trapping in 1993 based on habitat characteristics and distance of old nests from the river (Ogden and Swan I). This was unlike the earlier selections of territories by stratified random sampling. We selected the variables of habitat and distance of nest from the river to refine the burned and unburned comparisons which seemed to be inadequate to explain the variation we found in eagle ranging habits last year (Marzluff et al. 1992) and to determine if distance from the river is an important variable related to ranging habits. We also trapped at 3 territories with instrumented females (Cabin, Wildhorse, Grand View Sand Cliff) to capture males, and trapped at sites on the OTA in an effort to capture non-canyon nesting golden eagles wintering in the OTA and instrument them with both 80-g satellite backpack transmitters and 10-g conventional tail-mounted transmitters. We marked nestlings with patagial tags at Beecham and Pole 369 to identify these birds within their parents' territories.

We trapped as described in Marzluff et al. (1992), with the exception of using both jackrabbit and mule deer (*Odocoileus hemionus*) carcasses for bait, and occasionally burying traps in snow. Mule deer were used particularly when trapping for eagles on the OTA, as corvids were scarce and deer carcasses were more conspicuous than jackrabbits (see Marzluff et al. 1992 for importance of corvids when trapping eagles). These latter trap sites were selected after repeated observations of adult eagles at the same roost or perch sites within the OTA.

We monitored the breeding status of radio-tagged golden eagles at 7 territories during 1992 and 1993 (Cabin, PP&L 119, Grand View Sand Cliff, Wildhorse, Beecham, Black Butte, Beercase), and at 2 additional territories during 1993 (Ogden and Pole 369). Eagles were considered to be breeding if 1 member of the pair was seen in an incubating posture (M. Kochert, Bur. Land Manage., pers. commun.) or if eggs were seen, regardless of the condition of the nest. We selected 19 territories monitored by Study 3 as controls to compare with sites tended by radio-tagged adults. Control territories had no vacancies within the past 3 years, and no history of extensive manipulations during the egg-laying, incubation or chick-rearing periods.

We observed behaviors of instrumented eagles at 9 territories and 5 OTA winter areas as described by Marzluff et al. (1992). Observations of OTA wintering eagles were scheduled to correspond with the duty cycle (8 hrs on - 32 hrs off) of the satellite transmitter.

Satellite locations were obtained via the Argos Data Collection and Location System which codes each location for quality based on characteristics of the signals that were used to calculate each location (USFWS 1990). This scale increases from an undetermined precision (LQ 0) to a precision of 150 m (LQ 3).

Analyses.—Analyses of spatial use patterns for territorial eagles were described in Marzluff et al. (1992). These were also used to define use areas of the wintering OTA eagles. However, we defined the wintering areas in 4 ways: by using all locations provided by the satellite; by using only locations of LQ 1 - LQ 3; by using only locations of LQ 2 - LQ 3; and by using only locations obtained visually. We then compared the ranges obtained using visual locations with each of the ranges obtained using the different combinations of satellite locations using RANGES IV (Kenward 1993).

We tested the null hypothesis that radio transmitters had no effect on the probability of a pair fledging young by comparing the distribution of successful and failed nesting attempts between instrumented and control pairs using a Likelihood ratio Chi-squared test. We also analyzed the same data set using logistic regression with the probability of success (determined from historical success) as a covariate and a log-linear model examining the interactions of year, treatment and probability of success. The numbers of fledglings per nesting attempt were compared between instrumented and control groups using ANOVAs.

We assessed habitat selection by foraging eagles using procedures similar to those employed for prairie falcons. Foraging eagles were observed, and the location of hunting attempts were plotted on 1 : 24,000 topographic maps in the field. Plotting error was assumed to be ≤100 m. Therefore, a circle with a radius of 100 m was centered at each point and the habitat composition within that circle was calculated using a GIS by overlaying foraging points on the habitat map developed by Knick et al. (this volume). This used habitat was compared to the percentage of each habitat type available in the 95% harmonic mean home range for each eagle.

RESULTS

Activity of Prairie Falcons Inferred from Radio Telemetry

Influence of Telemetry Packages.—Nesting success of instrumented pairs tended to be lower than that of control pairs ($G^2_{adj} = 2.75$, $P = 0.10$, Table 2). There continued to be no significant impact of radio-tagging on behavior of prairie falcons in 1993. The immediate influence of capture and radio-tagging on behavior after release was not tested, but falcons generally perched and preened, and we observed nearly every instrumented falcon tugging at leg bands and the radio harness. These actions did not preclude other behaviors normally associated with breeding pairs (territory defense, courtship, copulation, and incubation) from occurring (2 falcons copulated within 1 hr after release, and 4 returned to aeries). Falcon behaviors on the second day post-release continued to include tugging at bands and the harness, but to a lesser degree, and we observed typical breeding behaviors (8 copulations, 7 falcons incubating, and 2 prey exchanges).

Instrumented falcons did not differ in fledging success compared with non-instrumented control pairs, nor were there any significant differences in the number of young fledged by all pairs or in the number fledged by successful pairs (Table 2). In 1991, pairs that included females with trans-

Table 2. Tests of effects of backpack radio-transmitters on different measures of prairie falcon productivity in the SRBOPA, 1991-93.

	Instrumented			Control					
	n	$\bar{x}$	sd	*n*	$\bar{x}$	sd	stat[a]	df	*P*
1991									
Fledging success (%)	26	73.1	-.-	42	81.0	-.-	0.57	1	0.45
Number of young fledged									
All pairs[b]	24	2.88	2.08	32	3.06	2.08	0.11	54	0.74
Successful pairs	17	4.06	1.14	24	4.08	1.14	0.005	39	0.95
Average nestling weight/brood (g)									
Males	13	581.4	24.6	20	564.9	24.8	3.29	28	0.08
Females	14	831.6	35.8	22	832.3	35.8	0.004	31	0.95
1992									
Fledging success (%)	29	86.2	-.-	47	76.6	-.-	1.09	1	0.31
Number of young fledged									
All pairs[b]	23	3.70	2.03	37	2.95	2.03	1.94	58	0.17
Successful pairs	19	4.47	0.92	26	4.19	0.92	1.02	43	0.32
Average nestling weight/brood (g)									
Males	18	557.8	34.1	27	552.9	33.6	0.21	40	0.65
Females	20	796.9	55.0	31	802.8	54.3	0.13	46	0.72
1993									
Fledging success (%)	31	22.6	-.-	47	40.4	-.-	2.75	1	0.10
Number of young fledged									
All pairsb	31	0.84	1.98	47	1.61	1.98	2.79	75	0.10
Successful pairs	7	3.71	1.24	18	4.11	1.24	0.79	23	0.48
Average nestling weight/brood (g)									
Males	5	566.4	33.9	14	564.0	32.3	0.47	14	0.51
Females	7	793.2	39.7	13	788.6	39.3	0.06	15	0.81
1991-93									
Fledging success (%)	86	59.3	-.-	136	65.4	-.-	0.85	1	0.36
Number of young fledged									
All pairs[b]	78	2.47	2.04	115	2.54	2.05	0.05	187	0.82
Successful pairs	43	4.08	1.20	68	4.13	1.11	0.04	105	0.84
Average nestling weight/brood (g)									
Males	36	567.6	35.0	61	556.3	31.8	2.51	88	0.12
Females	41	805.7	51.4	66	806.2	50.3	0.002	98	0.96

[a] Fledging success comparison made using Likelihood ratio $G^2_{(1)}$, all other comparisons made using 1-way analysis of variance with group degrees of freedom=1.
[b] Young fledged per pair does not include incomplete fledge counts and may underestimate actual productivity.

mitters tended to exhibit the highest rates of failure. In 1993, as in 1992, this sex-specific trend was not evident. When we combined all 3 years, the difference in failure rate with respect to sex was not significant ($G^2_{(1)} = 0.57$, $P = 0.45$). We also found no differences between weights of nestlings raised by instrumented or control pairs (Table 2).

Prairie falcons with transmitters and those without transmitters that were mated with radio-tagged individuals delivered prey to their nestlings at similar rates (Table 3). Prey delivery rate was not associated with the presence of a transmitter for either males or females, regardless of nestling age, and this comparison was not significant for rates in 1991-93 combined (Table 3). In addition, the amount of time radio-tagged falcons spent at the nest or in the territory was not correlated with the presence of a radio, and was nonsignificant for pooled data from 1991-93 (Table 3).

Weather Effects on Falcon Activity.—In 1993, as in previous years, weather influenced the movement (and/or our ability to detect movement) of

Table 3. Tests of effects of backpack radio-transmitters on different measures of prairie falcon nesting behavior in the SRBOPA, 1991-93.

	Nestlings <21 days old									Nestlings ≥21 days old								
	Instrumented			Control						Instrumented			Control					
	n	x	sd	n	x	sd	F	df	P	n	x	sd	n	x	sd	F	df	P
1991																		
Prey Delivery (items/hr)																		
Males	9	0.27	0.08	5	0.24	0.09	0.25	10	0.62	9	0.22	0.13	5	0.18	0.13	0.37	10	0.56
Females	5	0.16	0.10	9	0.23	0.10	1.73	10	0.22	5	0.17	0.09	9	0.19	0.09	0.06	10	0.81
Attendance at nest[a]																		
Males	9	16.3	9.5	5	17.0	9.6	0.02	10	0.90	9	9.7	6.1	3	5.9	6.2	-.-	.	-.-
Females	5	33.6	12.1	9	38.6	11.9	0.53	10	0.48	3	11.5	6.1	9	15.7	6.1	-.-	.	-.-
Attendance in territory[a]																		
Males	9	30.1	7.6	4	27.4	8.0	0.28	9	0.61	9	30.2	13.6	2	26.0	14.2	-.-	.	-.-
Females	4	44.9	10.9	9	47.4	10.4	0.14	9	0.72	2	28.3	13.0	9	40.7	12.4	-.-	.	-.-
1992																		
Prey Delivery (items/hr)																		
Males	8	0.25	0.16	7	0.27	0.16	0.05	11	0.84	8	0.28	0.11	7	0.27	0.11	0.01	11	0.93
Females	7	0.21	0.08	8	0.15	0.08	2.09	11	0.06	7	0.22	0.16	8	0.20	0.16	0.05	11	0.83
Attendance at nest[a]																		
Males	8	17.1	8.4	7	15.9	8.4	0.06	11	0.8	8	9.5	3.5	7	5.0	3.5	5.68	11	0.04[b]
Females	7	36.5	18.5	8	42.8	18.3	0.40	11	0.54	7	12.6	2.6	8	11.0	2.5	1.27	11	0.28
Attendance in territory[a]																		
Males	8	41.0	10.9	7	40.8	11.0	0.00	11	0.97	8	43.1	7.6	7	32.9	7.6	6.09	11	0.03[b]
Females	7	58.2	12.8	8	62.4	12.7	0.37	11	0.56	7	54.9	10.0	8	47.1	9.9	2.08	11	0.18
1993																		
Prey Delivery (items/hr)																		
Males	2	0.34	0.09	3	0.23	0.08	-.-	.	-.-	2	0.25	0.08	3	0.15	0.07	-.-	.	-.-
Females	3	0.39	0.03	2	0.24	0.04	-.-	.	-.-	3	0.22	0.12	2	0.23	0.13	-.-	.	-.-
Attendance at nest[a]																		
Males	2	19.8	6.9	3	11.8	6.5	-.-	.	-.-	2	7.5	4.7	3	9.4	4.5	-.-	.	-.-
Females	3	48.5	4.5	2	56.4	4.8	-.-	.	-.-	3	6.4	11.1	2	9.9	11.7	-.-	.	-.-
Attendance in territory[a]																		
Males	2	24.7	1.8	3	32.4	1.6	-.-	.	-.-	2	38.9	6.3	3	34.3	6.1	-.-	.	-.-
Females	3	67.3	3.9	2	54.0	4.2	-.-	.	-.-	3	35.2	8.0	2	36.4	8.3	-.-	.	-.-
1991-93																		
Prey Delivery (items/hr)																		
Males	19	0.26	0.11	15	0.26	0.12	0.01	30	0.93	19	0.25	0.12	15	0.22	0.12	0.92	30	0.35
Females	15	0.23	0.11	19	0.20	0.11	0.53	30	0.47	15	0.20	0.12	19	0.20	0.12	0.00	30	0.99
Attendance at nesta																		
Males	19	17.0	8.7	15	15.4	8.8	0.27	30	0.61	19	10.0	5.2	13	6.8	5.2	2.72	28	0.11
Females	15	38.8	14.4	19	41.5	14.3	0.29	30	0.59	13	12.0	6.0	19	13.9	5.9	0.78	28	0.38
Attendance in territory[a]																		
Males	19	35.8	11.0	14	33.0	11.1	0.48	29	0.49	19	36.7	9.3	12	31.1	9.5	2.14	27	0.13
Females	14	55.6	11.8	19	65.0	11.7	0.03	29	0.88	12	44.2	12.8	19	44.5	12.5	0.004	27	0.95

[a] Attendance means are the square root of the arcsine of the percent time spent at the nest or in the territory.
[b] Significant result

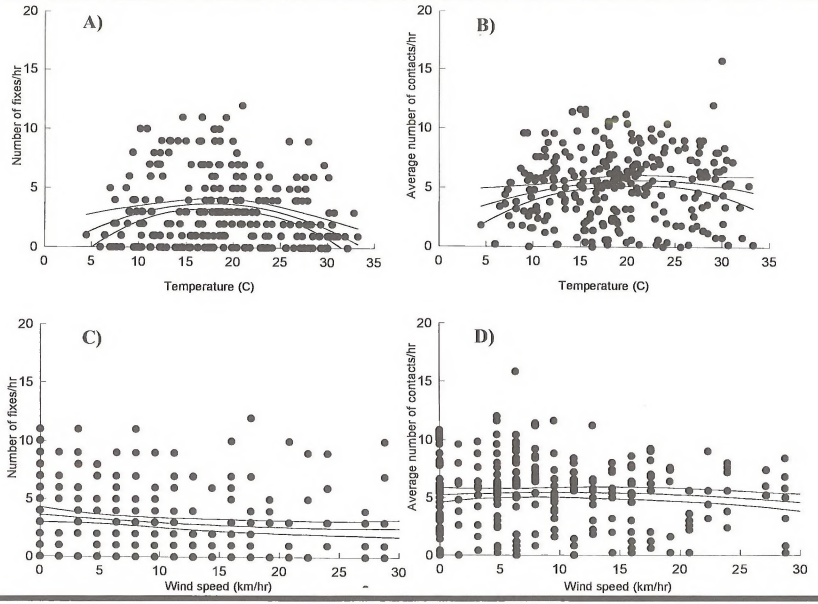


Fig. 3. Correlations between temperature and wind speed, and the average number of fixes <1,000 ha (A, C) and the average number of radio-tagged falcons contacted per hr (B, D). Weather was recorded with a portable weather station located at a receiver site. Least squares estimated regression lines and associated 95% confidence intervals are plotted through points.

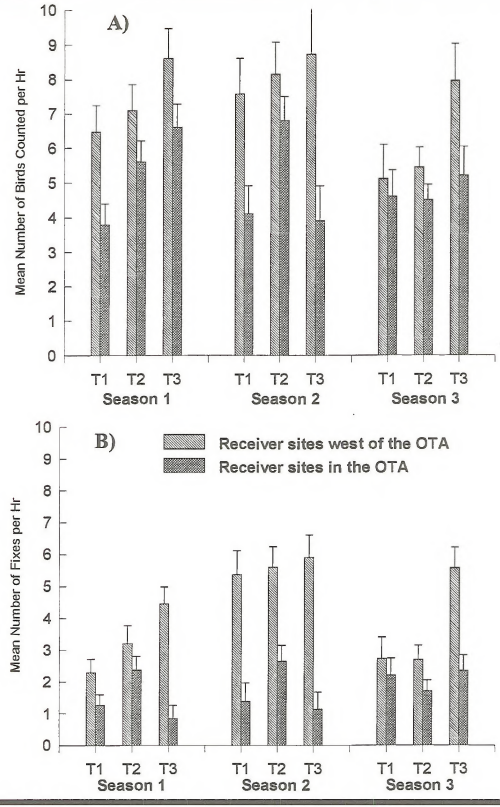


Fig. 4. Changes in radio-tagged falcon activity through the seasons (season 1 = 1 April - 15 May, season 2 = 16 May - 15 June, season 3 = 16 June - 1 August) and through the day (T1 = 0500-1000 hrs, T2 = 1100-1400 hrs, T3 = 1500-2100 hrs) in 1993. Mean number of birds contacted (A) and mean number of fixes obtained (B) + 1 SE are shown for 7 receiver sites in the OTA and 3 sites west of the OTA.

radio-tagged falcons. The number of birds contacted and number of fixes obtained were significantly associated with temperature (Fig. 3 A, B; curvilinear regression of fixes: $R^2 = 0.061$, $n = 284$, $P < 0.001$; curvilinear regression of contacts: $R^2 = 0.021$, $n = 284$, $P = 0.054$, Fig. 3B). Wind speed was associated with the number of fixes obtained ($r^2 = 0.013$, $n = 284$, $P = 0.05$) but not significantly correlated with the number of contacts ($r^2 = 0.009$, $n = 284$, $P = 0.11$, Fig. 3C). Examining the effect of wind speed and temperature simultaneously indicates a significant relationship between weather and the number of fixes or contacts (curvilinear multiple regression: $F_{(3, 280)} = 8.8$, $R^2 = 0.09$, $P < 0.001$). As in previous years, few falcons were located during high winds and extreme hot or cold temperatures (Marzluff et al. 1992).

Falcon Activity In and Out of the OTA.—In 1993, as in 1991 and 1992, falcons were more active around receiver sites west of the OTA than around sites inside the OTA (Fig. 4); both contacts (Fig. 4A; $F_{(1,6)} = 17.9$, $P = 0.005$) and fixes (Fig. 4B; $F_{(1,6)} = 9.9$, $P = 0.02$) were significantly higher west of the OTA. The number of fixes varied by both time and season in combination with location with respect to the OTA (repeated measures ANOVA using season, location, and time: season and time interaction: $F_{(4,24)} = 2.98$, $P = 0.057$; time: $F_{(2,12)} = 6.9$, $P = 0.01$; season and OTA interaction: $F_{(2,12)} = 10.9$, $P = 0.006$; time and OTA interaction: $F_{(2,12)} = 3.8$, $P = 0.052$). The number of contacts also varied with season and time, but showed no interaction with location of the nest with respect to the OTA (repeated measures ANOVA using season and time: time: $F_{(2,12)} = 7.7$, $P = 0.01$; season: $F_{(4,12)} = 3.3$, $P = 0.07$). Fixes west of the OTA increased throughout the day from 1 April - 15 May, whereas those in the OTA increased midday and then declined in late afternoon. This same pattern was observed from 16 May - 15 June. From 16 June - 1 August, counts of fixes in both areas changed little during the morning and noon hours; but during the late afternoon, numbers of fixes west of the OTA increased. During 1 April - 15 May, the numbers of contacts in the OTA and west of the OTA both increased as the day progressed. From 15 May - 15 June, however, the number of contacts in the OTA rose in midday and then dropped while the number of contacts west of the OTA continued to climb throughout the day; we observed the same pattern for fixes. From 16 June - 1 August, the pattern of contacts within the 2 regions mirrored each other, remaining steady from morning to midday and then increasing in late afternoon, although contacts west of the OTA increased more than those in the OTA.

Combining results from all years strengthened the conclusion that the number of falcons was significantly greater west of the OTA than inside the OTA. We obtained more fixes and contacted more birds per hour at sites west of the OTA than at sites inside the OTA (repeated measures ANOVA: main OTA effect for fixes: $\bar{x}_{west} = 3.0$, SE = 0.34; $\bar{x}_{shadow} = 1.5$, SE = 0.26; $F_{(1, 21)} = 22.8$, $P < 0.001$; main OTA effect for contacts: $\bar{x}_{west} = 5.7$, SE = 0.42; $\bar{x}_{shadow} = 3.9$, SE = 0.46; $F_{(1, 21)} = 20.5$, $P < 0.001$). There was also significant variation among years, with both fixes and contacts increasing significantly from 1991 to 1992 to 1993 (fixes/hr: $\bar{x}_{1991} = 1.5$, SE = 0.42; $\bar{x}_{1992} = 2.2$, SE = 0.34; $\bar{x}_{1993} = 3.6$, SE = 0.37; repeated measures ANOVA, main effect of year: $F_{(2, 21)} = 7.4$, $P < 0.001$; contacts/hr: $\bar{x}_{1991} = 3.6$, SE = 0.62; $\bar{x}_{1992} = 4.8$, SE = 0.51; $\bar{x}_{1993} = 6.1$, SE = 0.57; repeated measures ANOVA, main effect of year: $F_{(2, 21)} = 12.2$, $P < 0.001$).

Data grouped hourly by 2-week periods revealed patterns similar to those observed in previous years, but there were some small differences (Figs. 5, 6). In 1993, the number of birds contacted was high in April and remained high until late July, at which time birds began dispersing from the area. During May and June, a bimodal distribution of contacts punctuated by a lull at 1300 - 1400 hr was once again observed. Differences in number of contacts between west of OTA and OTA regions were less noticeable in 1993 than they have been in the past.

Spatial Use Patterns.—In previous years, we rarely obtained fixes on females early in the nesting cycle, but obtained fixes on males throughout the nesting period. In 1993, we obtained fixes from both males and females in similar proportions throughout the nesting cycle (Fig. 7). The "after nest failure" period produced more fixes than did any other period, especially for females. Differences in the number of fixes obtained on males and females by nesting cycle period was not significant ($X^2_{(5)} = 6.387$, $P = 0.270$).

Females defined the edge of their territory during the early stages of the nesting cycle (Fig. 8) in 1993, rather than during the later stages as observed in 1991 and 1992 . The "incubation" stage produced more outer fixes, and the "dispersal of fledglings" stage fewer outer fixes for males in

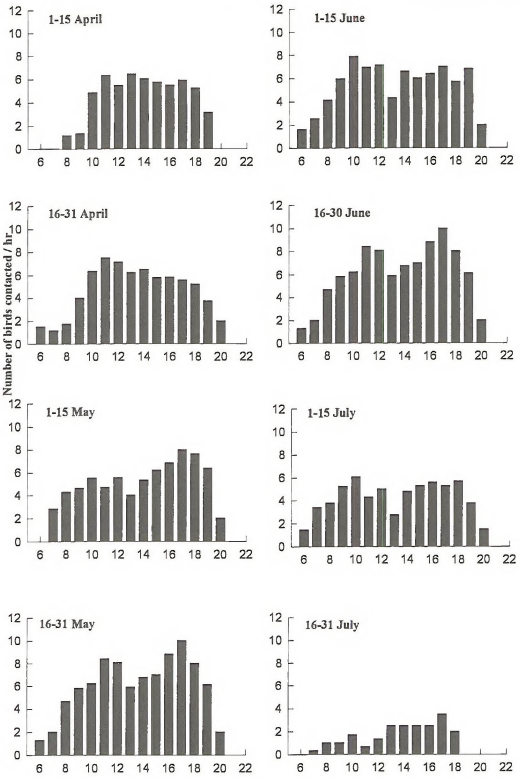


Fig. 5. Changes in radio-tagged falcon activity through the daylight hours and across the season at 3 receiver sites west of the OTA in 1993.

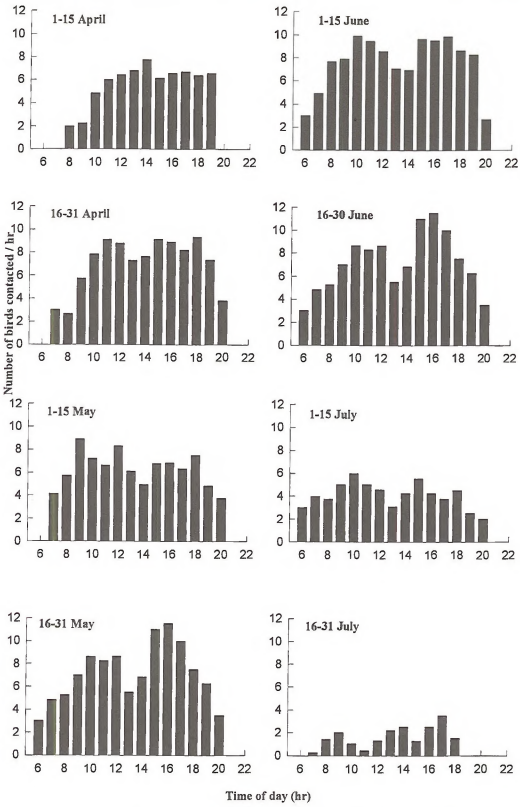


Fig. 6. Changes in radio-tagged falcon activity through the daylight hours and across the season at 10 receiver sites in the OTA in 1993.

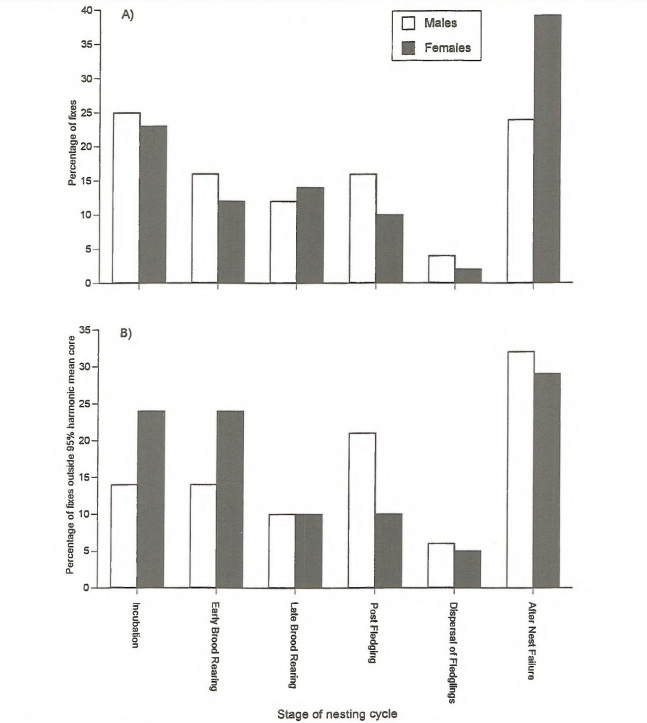


Fig. 7. The percentage of all location estimates (A) and the percentage of excursive locations (B) obtained on radio-tagged falcons throughout the study area in relation to stage in the breeding cycle in 1993. Stage of breeding for each falcon was determined by back-dating from the age estimate at the time of banding or from the last date of observation before nest failure. Incubation includes time when eggs were being incubated. Early brood-rearing incudes the time from hatching to 20 days post hatch. Late brood-rearing includes the time when nestlings were 21-40 days old. Post-fledging includes the first month after fledging when nestlings are dependent upon parental care. Dispersal of fledglings includes all time after 1 month post-fledging when fledglings are dispersing from their natal territories. After Nest Failure includes all times after the nesting attempt failed.

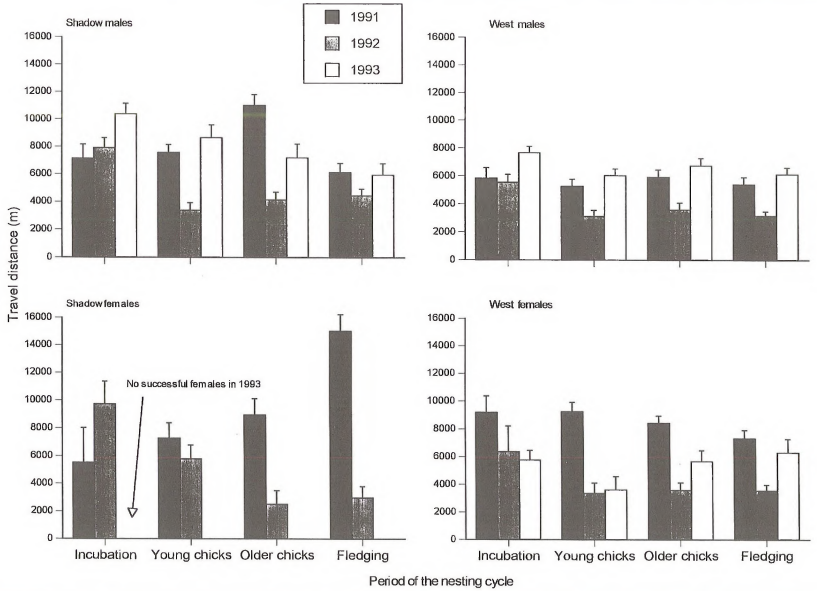


Fig. 8. Travel distance from the aerie for falcons, 1991-93. Male and female travel distances + 1 SE are plotted in respect to stage of the breeding cycle (see Fig. 7 for definition of stages) and are grouped by sex and location of nest site with respect to the OTA.

1993 (test for interaction between sex and year: $X^2_{(3)} = 15.76$, $P = 0.001$). The difference in the timing of male and female excursions to the edge of their home ranges was marginally non-significant ($X^2_{(5)} = 9.3$, $P = 0.098$).

Distances traveled from the aerie by males depended upon year, location of the nest with respect to the OTA, and the stage of the nesting cycle (Fig. 8; 3-way interactions: $F_{(6,1510)} = 3.1$, $P = 0.005$). Travel distances were greater in 1993 than in 1991 and 1992, and were greater for males in the OTA shadow than for males west of the OTA shadow. However, shadow males tended to reduce their travel distances through the nesting cycle, whereas west of shadow males maintained similar travel distances through the cycle. This reduction in travel distance by shadow birds during late brood-rearing and fledging was more pronounced in 1992 and 1993 than in 1991.

Distances traveled by females also depended upon their nest location, the stage of the nesting cycle, and the year of study (Fig. 8). Females that nest west of the OTA shadow traveled shorter distances than females nesting in the shadow, traveled the longest distances in 1991, and traveled similar distances from the aerie throughout the nesting cycle (effect of stage of nesting cycle: $F_{(3, 423)} = 1.3$, $P = 0.30$; effect of year: $F_{(2, 423)} = 26.0$, $P < 0.001$). Females in the OTA shadow increased travel distances throughout the nesting cycle in 1991, but decreased travel distances throughout the cycle in 1992 (2-way interaction: $F_{(3,110)} = 12.8$, $P < 0.001$).

Home range characteristics.—In 1993, we obtained 1,381 fixes with associated error ellipses <1,000 ha that met the criterion that 2 fixes not be taken on the same bird within 30 min. Maps of home ranges of falcons adequately sampled in 1993 are shown in Figs. 9 - 17. As discussed in Marzluff et al. (1991), home ranges are depicted as the area including 95% of the fixes around the harmonic mean. We present several other measures of home range size, travel distance and home range shape in Table 4.

As reported in 1992, successful pairs, unsuccessful pairs, and non-breeders differed in their ranging habits (Fig. 18A). Combining data from 1991-93, we have ranging data on 15 adequately sampled falcons that failed to rear nestlings successfully to fledging age, 39 falcons that successfully reared fledglings, and 14 falcons that never bred (Table 5). Mean and minimum distances traveled from the aerie and home range size tended to be greater for unsuccessful pairs than for successful pairs in both 1992 and 1993. However, this was not the case in 1991; successful pairs ranged farther than unsuccessful ones. This difference produced a significant interaction between year and success ($F_{(6, 56)} = 3.73$, $P = 0.002$). Unsuccessful pairs and non-breeders had larger home ranges than successful pairs, but these differences were not significant ($\bar{x}_{\text{failed and non-breeding}}$ = 23,779 ha, SE = 3,095, n = 21; $\bar{x}_{\text{successful}}$ = 16,925 ha, SE = 2,281, n = 39; $F_{(1,58)} = 3.2$, $P = 0.08$).

Adequately sampled falcons ranged significantly farther from their nests in 1993 than in either 1991 or 1992 (Fig. 19, Table 6; MANOVA testing year, sex, and location differences in all 3 ranging variables simultaneously: year effect: multivariate $F_{(6,74)} = 2.4$, $P = 0.04$), an effect also evident when only successful male breeders were analyzed (mean distance traveled from nest: $\bar{x}_{1991}$ = 6,985 m, SE = 680; $\bar{x}_{1992}$ = 7,108 m, SE = 601; $\bar{x}_{1993}$ = 6,789 m, SE = 951; MANOVA testing year, sex, and location differences within all 3 ranging variables simultaneously: year effect: multivariate $F_{(8,32)} = 3.2$, $P = 0.01$). Falcons in the OTA ranged farther from their nests than did falcons west of the OTA (Fig. 19; MANOVA: location effect: multivariate $F_{(3,37)} = 15.22$, $P < 0.001$). Successful males nesting in the shadow traveled farther than successful males nesting west of the shadow ($\bar{x}_{\text{shadow}}$ = 6,985, SE = 680 m; $\bar{x}_{\text{west}}$ = 5,082 m, SE = 451; MANOVA: location effect: multivariate $F_{(3,16)} = 3.8$, $P = 0.032$). The mean distance traveled was similar between male and female falcons, but males traveled to greater maximum distances and had larger home range sizes than females (Fig. 19; MANOVA: sex effect: multivariate $F_{(3,37)} = 4.25$, $P = 0.01$).

Large home ranges in 1993 are illustrated anecdotally by a single female (Ogden Rock Upstream) who nested in the same territory in 1992 and 1993. Her transmitter continued to function through the entire 1993 season, and we were able to obtain 29 fixes on her (as compared to 48 in 1992). In 1992, her maximum harmonic mean home range was 12,528 ha, her 95% harmonic mean home range was 8,693 ha, and her mean distance traveled from the aerie was 3,482 m. In 1993, these figures increased to 29,617 ha, 18,189 ha, and 5,225 m respectively.

Using cluster analysis to define home ranges of failed and successful nesters, falcons nesting in

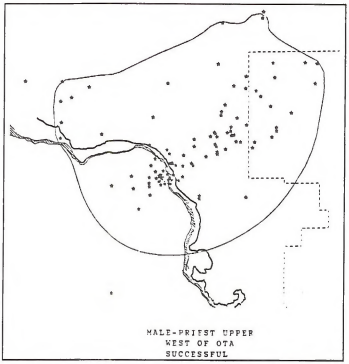


Fig 9

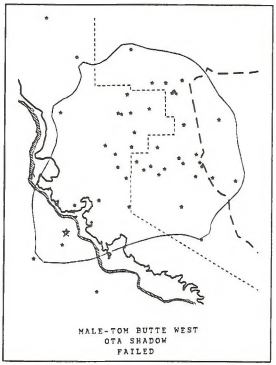


Fig 10

Figs. 9-17. Spatial use patterns of radio-tagged prairie falcons in 1993. Each bird was adequately sampled (see METHODS). Sex, nesting area, and breeding status for each individual are listed below each map. Individual locations are indicated with solid stars and aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and range road (thick, dashed line) are shown for orientation, when present in the range. Each map is drawn to the same scale (1 : 351,563), and oriented with north at the top of the page, unless otherwise noted.

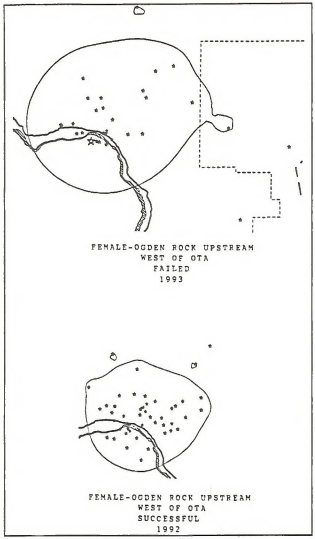

FEMALE-OGDEN ROCK UPSTREAM
WEST OF OTA
FAILED
1993
FEMALE-OGDEN ROCK UPSTREAM
WEST OF OTA
SUCCESSFUL
1992

Fig 11

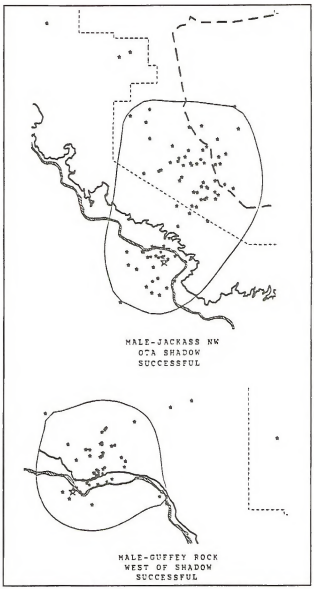
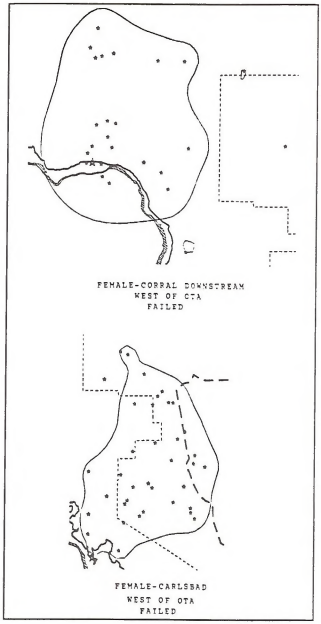

MALE-JACKASS NW
OTA SHADOW
SUCCESSFUL
MALE-GUFFEY ROCK
WEST OF SHADOW
SUCCESSFUL

Fig 12

Fig 15


FEMALE-CORRAL DOWNSTREAM
WEST OF OTA
FAILED
FEMALE-CARLSBAD
WEST OF OTA
FAILED

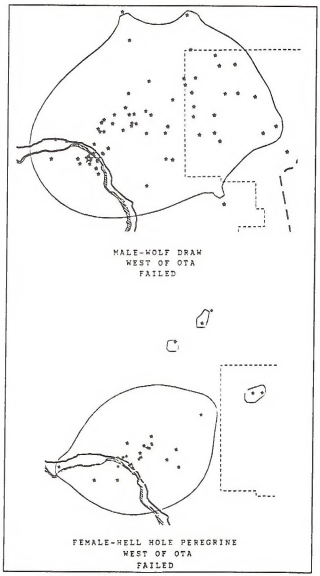
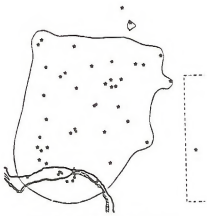
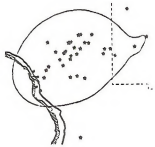

MALE-WOLF DRAW
WEST OF OTA
FAILED
FEMALE-HELL HOLE PEREGRINE
WEST OF OTA
FAILED

Fig 13

MALE NON-BREEDING



FEMALE-CATTLEGUARD GATE
WEST OF OTA
SUCCESSFUL



FEMALE-PRIEST RAPIDS I
WEST OF OTA
FAILED

Fig. 14

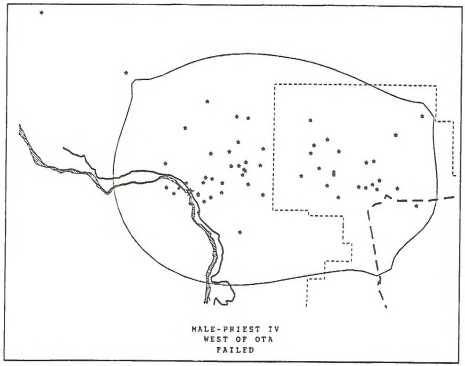

MALE-PRIEST IV
WEST OF OTA
FAILED

Fig 16

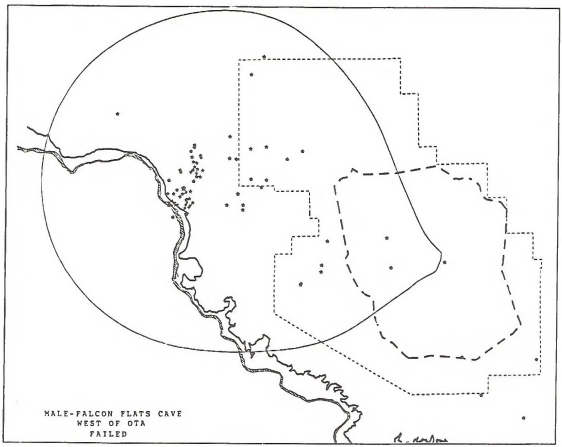

MALE-FALCON FLATS CAVE
WEST OF OTA
FAILED

Fig 17

Table 4. Home range characteristics of paired prairie falcons in the SRBOPA determined from radiotelemetry in 1993. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hc-harmonic center, Ac-arithmetic activity center.

				Mean distance from:				Max distance from:			Harmonic Mean Home Range				Convex Polygon Home Range			
Nesting[a] Area	Sex	OTA[b]	N	Nest	Hc	Ac	Hc-Nest	Nest	Hc	Ac	Max	95%	90%	50%	Max	90%	70%	50%
RoIRT	F	S	41												22,193	19,684	14,165	5,046
OgRUS	M	W	57												22,227	9,554	7,447	2,359
CGG	F	W	49	6,610	2,517	5,248	1,293	15,220	15,710	10,350	24,554	16,541	13,055	2,316	16,770	13,370	7,263	4,323
Unk	M	N	48												64,922	46,132	27,820	12,480
BPtF	M	S	66												64,062	3,985	21,258	6,537
MGUS	M	W	93	91,891	2,343	6,715	116	20,090	19,680	114,220	54,495	31,902	25,077	5,327	29,560	23,430	15,530	11,750
RsUrS	F	S	8	6,926	3,065	5,035	1,569	10,970	9,533	5,644	772	772	685	365	4,807	4,592	2,773	550
Unk	M	N	8												10,351	10,351	6,375	2,587
CoDS	F	W	28	6,505	2,685	6,021	0	17,930	17,930	14,440	27,280	23,083	14,534	1,732	23,350	12,070	6,694	1,095
FFC	M	W	73	7,324	1,287	7,124	1,292	37,360	36,430	32,900	151,109	81,364	38,279	2,282	45,860	21,890	3,452	984
WhBNE	M	S	67												51,134	37,795	21,795	6,386
PrUp	M	W	103	6,186	97	5,654	652	17,400	16,900	15,900	57,338	37,146	30,522	2,559	37,060	26,380	10,890	4,971
HHP	F	W	29	4,615	27	4,316	3,251	1,570	12,470	12,440	14,660	13,507	12,491	993	13,050	10,740	1,297	529
ConFl	M	S	24												41,543	40,420	37,175	8,339
HndDw	F	S	9												3,810	3,810	3,862	1,096
WoDw	M	W	69	7,070	66	5,547	17,920	16,690	12,860	35,852	29,341	20,683	2,480	23,320	18,310	7,416	2,801	21,360
Csbd	F	S	38	10,610	3,384	5,472	6,011	10,150	13,370	10,340	17,676	15,480	13,138	3,473	13,400	12,410	8,049	4,810
Ptrgl	F	W	25												19,019	10,242	6,919	1,576
Unk	F	N	19												14,614	12,772	6,636	1,836
PrIV	M	W	61	8,693	1,466	6,984	768	21,960	21,690	24,630	114,476	52,044	20,819	6,882	40,090	18,280	15,200	5,365
GufRk	M	W	56	4,286	266	2,842	1,622	19,230	17,620	15,940	39,590	11,749	6,311	1,518	13,860	3,801	1,890	1,054
BBl	M	S	36	10,120	68	7,556	2,907	29,570	28,510	26,450	97,895	46,335	37,151	5,816	54,580	23,950	12,700	3,978
Fang	F	W	2	1,921	48,240	48,240	0	723	48,240	24,120								
SkCME	M	S	39												25,449	16,230	14,194	4,367
TBtW	M	S	53	10,250	31,901	6,244	123	19,330	19,264	14,870	49,548	27,906	24,678	5,643	30,970	24,700	18,790	13,490
PrRpI	F	W	41	4,192	859	2,754	4,386	10,760	8,573	7,060	10,017	7,050	3,273	849	6,265	3,893	1,642	1,113
JaNW	M	S	89	7,025	85	5,293	7,990	23,980	20,210	19,680	80,972	21,879	11,596	3,141	25,150	9,826	7,462	4,973
RsDw	F	S	20												12,526	12,625	9,882	2,170
Unk	M	N	5												593	593	517	238
SKBl	M	S	35												98,528	36,164	23,896	6,755
JBBGE	M	S	31												26,228	11,372	10,332	1,951
FvrBU	F	S	29												30,908	27,008	18,994	4,481
OgRUS	F	W	29	5,225	1,554	4,855	1,576	17,990	16,610	15,110	29,617	18,189	15,987	1,898	19,280	7,231	2,217	860

[a] Nesting area names are as follows: RoIRT=Rosie I Red-tail, OgRUS=Ogden Rock Upstream, CGG=Cattleguard Gate, BPtF=Balls Point Face, MGUS=Mother Giant Upstream, RsUrS=Rosie Upriver South, CoDS=Colt Downstream, FFC=Falcon Flats Cave, WhBNE=Wildhorse Butte NE, PrUp=Priest Upper, HHP=Hell Hole Peregrine, ConFl=Conservancy Flats, HndDw=Henderson Draw, WoDw=Wolf Draw, Csbd=Carlsbad, Ptrgl=Petroglyphs, PrIV=Priest IV, GufRk=Guffey Rock, BBl=Black Butte I, Fang=Fang, SkCME-Sinker Creek Mouth East, TBtW=Tom Butte West, PrRpI=Priest Rapids I, JaNW=Jackass NW, RsDw=Rosie Draw, SKBl=Sinker Bluff, JBBGE=Jackass BBGE, FvrBU=Fever Basin Upstream, Unk=Unknown

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow, N=no known nesting area.

Table 4 (cont.). Home range characteristics of paired prairie falcons determined from radiotelemetry in 1993. Distances are recorded in meters and home ranges are recorded in hectares. Table headings are abbreviated as follows: Hr-sum of the reciprocal distance (d-1) to each fix, divided by the number (n) of distances and then re-inverted (i.e. n/$\sum$d-1), D-dispersion, Sk-skewness, K-kurtosis, Sp-spread.

				Home Range Shape					Use of OTA	
					Harmonic Mean				No. Locations Inside:	
Nesting[a] Area	Sex	OTA[b]	N	Maximum Polygon width	Hr	D	Sk	K	Sp	OTA (%)	Range Rd (%)
RoIRT	F	S	41			1.62	2.66	2.97	5,032	19 (46.34)	2 (4.88)
OgRUS	M	W	57			1.54	1.85	2.5	3,406	1 (1.75)	0 (0)
CGG	F	W	49	17,350	2,570	1.94	4.32	3.13	4,154	1 (2.13)	0 (0)
Unk	M	N	48		5,244	3.58	11.51	5.55	8,125	12 (25)	8 (16.66)
BPtF	M	S	66		2,353	3.06	0.58	6.82	5,242	24 (36.36)	3 (4.55)
MGUS	M	W	93	24,760	2,369	2.24	6.66	4.72	4,988	40 (43.48)	4 (4.35)
RsUrS	F	S	8	10,970	3,504	1.04	1.22	1.48	4,996	2 (28.57)	0 (0)
Unk	M	N	8		8,825	0.75	0.64	1.07	12,443	3 (37.50)	2 (25)
CoDS	F	W	28	21,720	2,785	1.16	1.89	1.87	44,991	1 (3.70)	0 (0)
FFC	M	W	73	46,000	1,305	2.28	7.75	5.17	2,953	13 (18.06)	4 (5.56)
WhBNE	M	S	67		2,896	3.89	10.22	7.41	5,593	40 (59.70)	4 (5.97)
PrUp	M	W	103	28,580	99	9.60	361.00	206.70	2,109	14 (13.73)	0 (0)
HHP	F	W	29	19,620	29	5.22	30.19	65.50	359	2 (7.14)	0 (0)
ConFl	M	S	24		5,389	1.24	1.23	1.90	8,333	8 (33.33)	6 (25)
HenDw	F	S	9		3,892	1.20	2.59	1.67	5,423	4 (44.44)	0 (0)
WoDw	M	W	69	21,360						18 (26.47)	0 (0)
Csbd	F	S	38	18,640	3,476	1.44	1.57	2.02	4,865	26 (70.27)	4 (10.81)
Ptrgl	F	W	25		2,097	1.40	4.56	2.37	3,542	0 (0)	0 (0)
Unk	F	N	19		2,630	1.02	0.61	1.62	4,266	3 (15.79)	0 (0)
PrIV	M	W	61	39,080	1,490	3.51	15.12	10.95	4,650	21 (35)	2 (3.33)
GufRk	M	W	56	21,250	271	6.13	51.93	35.19	1,555	1 (1.82)	0 (0)
BBl	M	S	36	38,560	70	8.20	660.98	8.38	71	7 (20)	12 (34.29)
Fang	F	W	2								
SkCME	M	S	39		2,313	2.86	0.96	5.45	4,404	18 (46.15)	1 (2.56)
TBtW	M	S	53	24,990	3,252	3.56	9.73	5.55	5,062	22 (42.31)	3 (5.77)
PrRpl	F	W	41	12,290	882	3.24	5.58	7.49	2,033	4 (10)	0 (0)
JaNW	M	S	89	26,520	86	9.10	290.60	136.40	1,295	41 (46.59)	10 (11.34)
RsDw	F	S	20		2,082	2.75	7.38	5.90	4,461	8 (40)	2 (10)
Unk	M	N	5		4,822	0.93	0.01	1.33	6,919	1 (20)	0 (0)
SkBl	M	S	35		4,045	1.37	2.48	2.14	6,312	14 (40)	4 (11.43)
JBBGE	M	S	31		2,500	2.04	4.37	3.44	4,208	4 (12.90)	15 (48.39)
FvrBu	F	S	29		4,753	1.09	1.12	1.49	6,510	8 (27.59)	1 (3.45)
OgRUS	F	W	29	21,270	1,607	1.50	2.04	2.95	3,111	2 (6.90)	0 (0)

[a] Nesting area names are as follows: RoIRT=Rosie I Red-tail, OgRUS=Ogden Rock Upstream, CGG=Cattleguard Gate, BPtF=Balls Point Face, MGUS=Mother Giant Upstream, RsUrS=Rosie Upriver South, CoDS=Colt Downstream, FFC=Falcon Flats Cave, WhBNE=Wildhorse Butte NE, PrUp=Priest Upper, HHP=Hell Hole Peregrine, ConFl=Conservancy Flats, HndDw=Henderson Draw, WoDw=Wolf Draw, Csbd=Carlsbad, Ptrgl=Petroglyphs, PrIV=Priest IV, GufRk=Gufley Rock, BBl=Black Butte I, Fang=Fang, SkCME=Sinker Creek Mouth East, TBtW=Tom Butte West, PrRpl=Priest Rapids I, JaNW=Jackass NW, RsDw=Rosie Draw, SkBl=Sinker Bluff, JBBGE=Jackass BBGE, FvrBU=Fever Basin Upstream, Unk=Unknown

[b] OTA abbreviations are as follows: S=nesting area within the OTA shadow, W=nesting area west of the OTA shadow, N=no known nesting area.

Table 5. Travel distance and home range characteristics for successful, unsuccessful, and non-breeding prairie falcons in the SRBOPA, 1991-93.

	95% core area (ha)			Maximum travel distance from aerie (m)			Mean travel distance from aerie		
(m)	N	Mean	SE	N	Mean	SE	N	Mean	SE
Successful	39	16,924	1,849	3	16,156	959	39	7,955	2,251
Unsuccessful	15	22,374	5,289	12	19,977	2,166	12	6,820	633
Non-breeders	6	27,291	11,137	-	-	-	-	-	-

the OTA shadow did not have significantly different home ranges from falcons west of the OTA ($\bar{x}_{OTA}$ = 15,134 ha, SE = 1911; $\bar{x}_{west\ of\ OTA}$ = 13,233 ha, SE = 3090; $F_{(1,57)} = 0.26$, $P = 0.61$). Differences occurred, however, among years and between sexes (Fig. 20). In 1991 and 1992, males and females had similar home range sizes, but in 1993 male ranges were twice as large as female home ranges (1993: $\bar{x}_{males}$ = 33,995 ha, $\bar{x}_{females}$ = 16,279 ha; year and sex interaction in MANOVA: $F_{(2,47)} = 4.0$, $P = 0.03$). When only successful pairs were considered, home range size varied by year alone ($F_{(2,33)} = 10.7$, $P < 0.001$).

Internal Anatomy of Home Ranges.—Prairie falcons had distinct core use areas within their large home ranges (Table 6). Core areas are indicated by a high number of fixes occurring in a small area. A value of 75% for a 50% core area, for instance, indicates that 75% of all fixes were located in 50% of the home range area. All years considered, large home ranges did not have better de-

Table 6. Measurements of travel distance and home range characteristics of prairie falcons in the SRBOPA, 1991-93.

		Mean distance from nest	Max. distance from nest	95% harmonic mean home range	95% cluster defined home range	% of fixes in 95% core area	% of fixes in 85% core area	Number of nuclei in 95% area	Number of nuclei in 85% area
Males[a]	N	30	30	33	33	33	33	32	32
	Minimum	2,136	5,872	2,676	1,367	25.5	8.8	1	1
	Maximum	91,891	37,360	81,364	81,364	84	48.5	5	8
	Mean	8,521	17,986	22,864	16,889	52.4	27.6	2.4	2.7
	SE	2,904	1,242	2,867	3,012	2.9	2.0	0.3	0.2
Females[a]	N	21	21	27	26	26	26	26	26
	Minimum	2,855	9,241	3,907	575	10.3	5.7	1	1
	Maximum	12,880	32,250	45,073	27,009	94	78	5	5
	Mean	6,499	15,727	14,995	10,640	65.8	33.2	2.2	2.7
	SE	664	1,303	1,965	1,545	4.4	3.3	0.3	0.2
1991[b]	N	17	17	19	19	19	19	19	19
	Minimum	2,535	6,256	2,676	1,736	17.5	8.6	1	1
	Maximum	12,880	32,250	45,073	24,469	94.2	49.4	4	8
	Mean	7,421	18,631	17,646	9,970	58.1	25.8	1.7	3.2
	SE	721	1,775	2,867	1,587	5.3	2.4	0.2	0.4
1992[b]	N	20	20	21	21	21	21	21	21
	Minimum	2,136	5,872	3,414	575	10.3	5.7	1	1
	Maximum	7,307	24,120	41,796	18,073	84.2	51.7	5	4
	Mean	4,210	13,924	13,747	6,909	55.5	30.2	1.7	2.0
	SE	332	910	2,142	1,186	3.9	2.7	0.2	0.2
1993[b]	N	13	13	19	18	18	18	17	17
	Minimum	4,192	10,150	7,050	7,051	27	10	1	1
	Maximum	91,891	37,360	81,364	81,364	92	78	5	4
	Mean	13,481	19,002	27,001	27,219	63.6	35.7	3.7	3.1
	SE	6,558	1,875	4,095	4,322	4.6	4.2	0.4	0.2

[a]Includes birds from all years.
[b] Includes both sexes within given year.

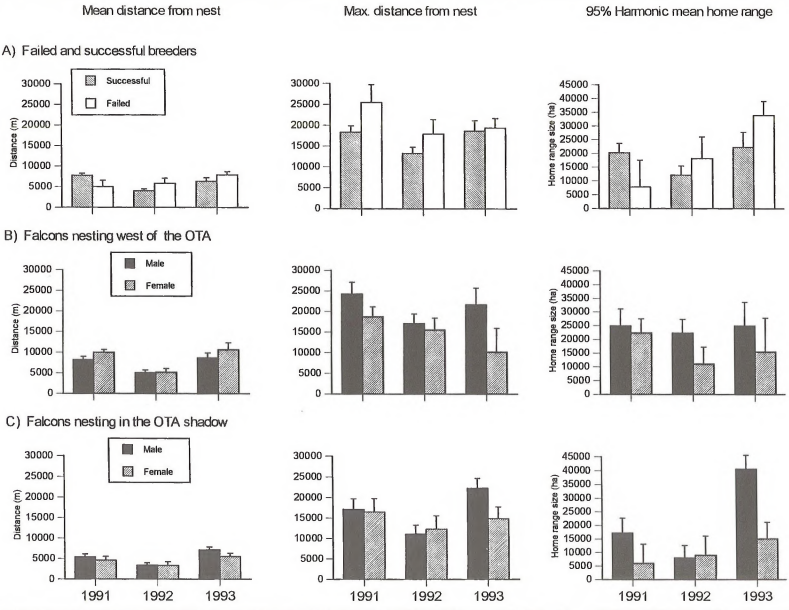


Fig. 18. Ranging characteristics + 1 SE for failed and successful pairs (A), and male and female falcons by nesting location with respect to the OTA (B, C).

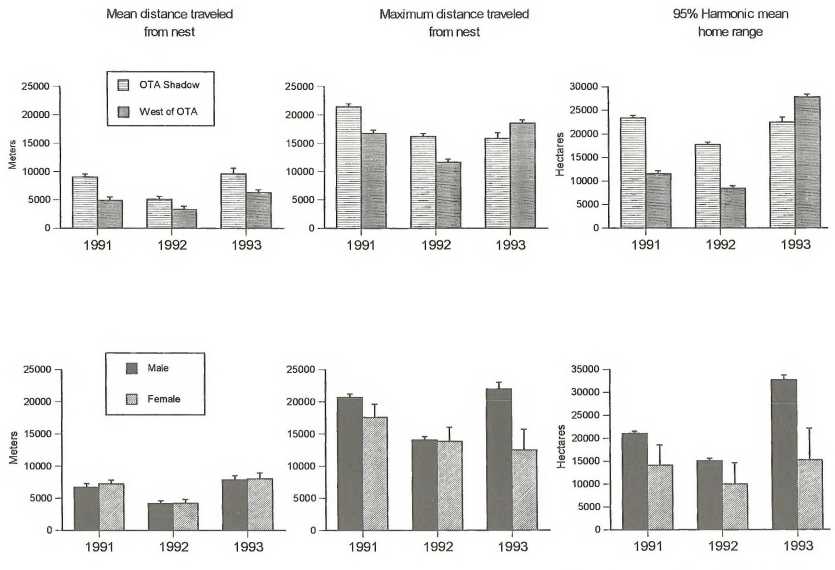


Fig. 19. Ranging characteristics + 1 SE for all falcons by nesting location with respect to the OTA (A), and by sex (B).

fined cores or more core areas than small home ranges. Correlations between home range size and the percent of the total area delineated by 95% and 85% of the fixes were not significant (harmonic mean home range size correlated with percent of total area including 95% of fixes: $r^2 < 0.001$, $n = 58$, $P = 0.99$; 85% of fixes: $r^2 < 0.001$, $n = 58$, $P = 0.871$). Correlations between home range size and the number of activity centers defined within the area encompassing 95% of the fixes were highly significant, whereas activity centers encompassed by 85% of the fixes were not significantly correlated with home range size (harmonic mean home range size correlated with number of activity centers in area including 95% of fixes: $r^2 = 0.277$, $n = 57$, $P < 0.001$; 85% of fixes: $r^2 = 0.002$, $n = 57$, $P = 0.728$). Data for only 1993 show the same results (95% of fixes: $r^2 = 0.012$, $n = 18$, $P = 0.671$; 85% of fixes: $r^2 = 0.080$, $n = 18$, $P = 0.254$; number of nuclei in 95% area correlated with home range size: $r^2 = 0.43$, $n = 17$, $P = 0.04$; number of nuclei in 85% area correlated with home range size: $r^2 = 0.001$, $n = 17$, $P = 0.92$).

When only successful nesters were considered, the percent of the total home range incorporating 95% and 85% of all fixes on a falcon did not differ between falcons nesting in the OTA shadow and those nesting west of the OTA, between years, or between sex of bird (multivariate F-tests of main effects; effects of sex: $F_{(2,25)} = 2.5$, $P = 0.13$; effects of year: $F_{(2,25)} = 0.5$, $P = 0.61$; effects of nest location: $F_{(2,24)} = 0.011$, $P = 0.99$). Using both failed and successful nesters showed a significant year and sex interaction (year and sex interaction, multivariate F: $F_{(4,92)} = 2.7$, $P = 0.04$); males had smaller 95% core areas in all years except 1992, when males and females had equal range sizes (Fig. 19). Even though females had higher use of 95% core areas than males, this was not reflected in their use of 85% core areas, except in 1993. During other years, the 85% use area was equal for males and females.

Core areas were commonly distributed among several activity centers, and cluster analyses identified these activity centers in the 95% core areas and in the 85% core areas (Table 6). Falcons had ranges with more than twice as many activity centers in 1993 than in previous years. This was especially conspicuous within the 95% core area; within the 85% core area, 1991 and 1993 showed similar results (Table 6). Analysis of both measures of activity centers simultaneously revealed a significant year effect for successful falcons and for successful falcons grouped with failed falcons (successful only: $F_{(2,24)} = 5.0$, $P = 0.02$; both successful and unsuccessful: $F_{(4,90)} = 9.6$, $P < 0.001$). The number of activity centers was not different between males and females (successful only: $F_{(2,24)} = 0.3$, $P = 0.71$; both successful and unsuccessful: $F_{(2,45)} = 0.15$, $P = 0.87$) or between birds nesting in the OTA versus west of the OTA (successful only: $F_{(2,24)} = 0.4$, $P = 0.66$; both successful and unsuccessful: $F_{(2,45)} = 0.6$, $P = 0.54$).

Direct Observations of Falcons.—The activities of radio-tagged falcons influenced our ability to estimate their location by remote telemetry. Relatively precise estimates (linear error <2 km) were obtained every time a position fix was attempted on a falcon flying >10 m above ground level (AGL; $n = 21$ attempts). However, only half of the attempts to precisely locate falcons when they were flying or perched <10 m AGL were successful ($n = 8$ of 15 attempts had linear errors <2 km). We were able to obtain a precise location estimate significantly more often when the falcon was flying >10 m AGL than when the falcon was perched or flying <10 m AGL ($X^2_{(1)} = 9.44$, $P < 0.005$). There was considerable variation in the linear error between a direct observation and an estimated fix ($n = 29$, $\bar{x} = 2{,}181$ m, SE = 961 m, max = 27, 539 m, min = 116 m). Linear errors associated with visually "estimated" locations (when the bird was flying) were over twice as great as linear errors for "known" locations (when the bird was perched), but this difference was not significant (estimated: $\bar{x} = 2{,}745$ m, $n = 19$, actual: = $\bar{x}$ 1,052 m, $n = 11$, $F_{(1,28)} = 0.76$, $P = 0.39$).

Use of the OTA.—As in previous years, falcons tended to range northeast from their aeries toward the OTA, but in sharp contrast to limited use of the OTA in 1992, 29 of the 30 falcons instrumented west of OTA shadow or in the OTA shadow used the OTA in 1993, and 18 of these were located inside Range Road. Only 2 birds were located inside the OTA ≥50% of the time, but 6 birds were located in the OTA >40% of the time. As in 1991 and 1992, birds categorized as nesting in the OTA shadow were located inside the OTA boundaries ($\bar{x} = 39.6\%$, SD = 14.5, $n = 15$) more often than birds categorized as nesting west of the OTA ($\bar{x} = 13.3\%$, SD = 13.4, $n = 14$, $F_{(1,27)} = 25.8$, $P < 0.001$). Two of the 5 radio-tagged birds captured east of the OTA spent an average of 28.75% ($n = 4$) of their time inside the OTA, and 1 was recorded 25% ($n = 2$) of the time inside

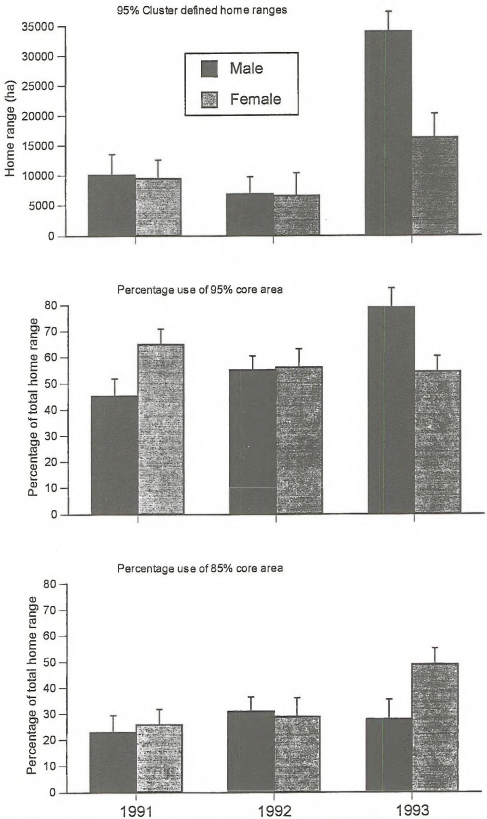


Fig. 20. Home ranges of prairie falcons, 1991-93, including 95% of the area used as defined by cluster analysis, and percentage use of 95% and 85% core areas. Means + 1 SE are plotted for falcons.

Range Road. Both of these birds were non-breeders. The 3 birds that bred east of the OTA shadow were never detected within our tracking zones, and no fixes were obtained, although their radios were infrequently received southeast of the OTA during scanning.

Influence of Military Activity on Ranging Habits.—Falcons traveled farther from their aeries on days with firing than on days without firing. Samples were sufficient to make this comparison only for males in 1993 ($\bar{x}_{\text{travel distance when firing}}$ = 7,756 m, SE = 356, n = 331; $\bar{x}_{\text{no firing}}$ = 6,440 m, SE = 565.4, n = 128; $F_{(1,455)}$ = 3.9, P = 0.05). Successful males nesting in the OTA shadow ranged farther than those nesting to the west ($\bar{x}_{OTA}$ = 7795 m, SE = 591, n = 98; $\bar{x}_{west}$ = 6400, SE = 311, n = 361; $F_{(1,458)}$ = 4.4, P = 0.04). However, unlike previous years, the effect of firing on travel distance did not depend on the location of the aerie with respect to the OTA (2-way interaction between firing and location: $F_{(1,455)}$ = 0.35, P = 0.55).

In 1991 and 1992, falcons did not appear to avoid the area inside Range Road when firing occurred. This was also the case in 1993. We obtained 237 fixes on falcons inside the OTA when ranges were firing and 83.1% (n = 197) were located outside Range Road. Similarly, 82.6% of the 92 locations obtained inside the OTA when firing did not occur were outside of Range Road ($X^2_{(1)}$ = 0.01, P = 0.91). However, in 1993 we took a finer-scaled approach to this analysis by looking at the location of fixes inside Range Road with respect to the location of firing at the time the fix was obtained. This analysis indicated that falcons were avoiding firing areas, but they did so by moving elsewhere *inside* Range Road. When firing occurred in the north half of the impact area, falcons were located there 30.1% of the time (n = 12); they were located in the south half the remaining 69.9% of the time (n = 27). In contrast, when firing did not occur in the north half of the impact area, falcons were there 64.7% of the time (n = 11); they were south only 35.3% of the time (n = 6). This adjustment of location within the impact area with respect to the location of firing was significant ($X^2_{(1)}$ = 5.62, P = 0.02).

Habitat Use of Falcons.—A preliminary analysis of habitat use showed that little selection occurred (Fig. 21). Two falcons avoided low density grasslands, but 1 selected them. One falcon selected for medium density sagebrush (*Artemisia tridentata*), but another avoided that habitat type. One falcon each avoided agricultural and medium density shadscale (*Atriplex confertifolia*) habitats.

Dispersal of Falcons.—In 1993, falcons began to depart the study area in late June, as in 1992 (Fig. 22). The pattern of dispersal was intermediate between 1991 and 1992 through the middle of July. However, from the second half of July through August, dispersal was more rapid in 1993 than in either previous year. Only 1 male (Tom Butte West) remained in the study area after the first week of August (he has remained through mid-December). The pattern of dispersal varied significantly among the 3 years of study (comparing the number of falcons dispersing per 2-week interval 23 July - 7 August: $X^2_{(2)}$ = 14.67, P = 0.005). As in previous years, location of the nest with respect to the OTA did not influence the timing of dispersal in 1993 ($F_{(2,27)}$ = 0.05, P = 0.83) or in 1991-93 ($F_{(2,76)}$ = 1.56, P = 0.22).

Ranging Behavior Inferred by Telemetry Compared with Nesting Observations.— As in previous years, wide-ranging birds (as determined by telemetry) were seen less in their territories than were close-ranging birds. In 1993, sample sizes were small and correlations between range sizes and percent of time spent in territory were not significant (all P's > 0.15). For all 3 years combined, however, as the maximum and mean travel distances from the aerie and home range size increased, the percent of time the falcon was observed in the territory decreased (maximum distance: r^2 = -0.484, n = 29, P = 0.008; mean distance: r^2 = -0.50, n = 29, P = 0.006; 95% home range: r^2 = -0.375, n = 29, P = 0.045).

Association of Ranging Behavior and Fledgling Productivity.—Ranging habits had little correlation with fledgling productivity. Neither the maximum travel distance from the aerie nor the 95% harmonic mean home range size varied with the number of young fledged (both P's > 0.40). Sample sizes were small, but there was a slight correlation between the mean travel distance from aerie and the number of young (r^2 = 0.85, n = 4, P = 0.076). For all years combined, as the number of fledglings increased, the maximum distance traveled decreased. (r^2 = 0.2, n = 38, P = 0.006). As the number of fledglings increased, time spent in the OTA tended to decrease when all years were combined (r^2 = 0.1, P = 0.055).

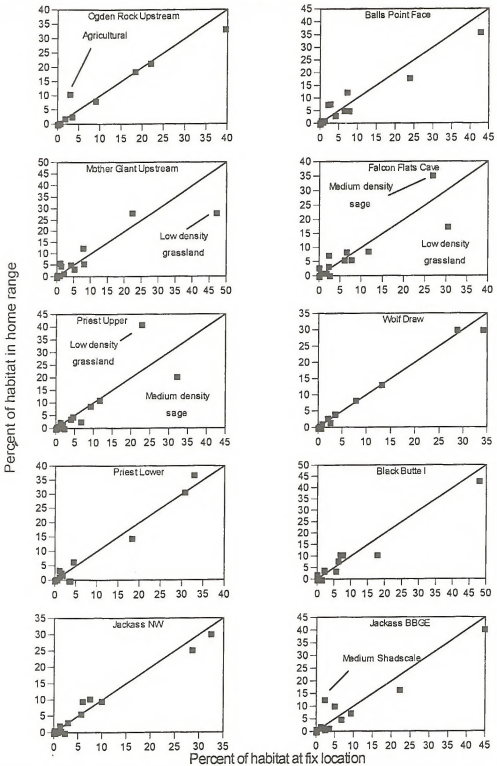


Fig. 21. Habitat use in relation to habitat availability in prairie falcon 1993 home ranges. Points within plots for each eagle represent different habitat types. Percentage of each habitat was averaged for all locations and plotted on the X axis. Percentage of each habitat in the entire 1993 home range is plotted on the Y axis. The diagonal line indicates use of habitat in direct proportion to availability. Points above this line indicate habitats that are avoided. Points below this line indicate habitats that selected. Points indicating extreme avoidance or selection are labelled.

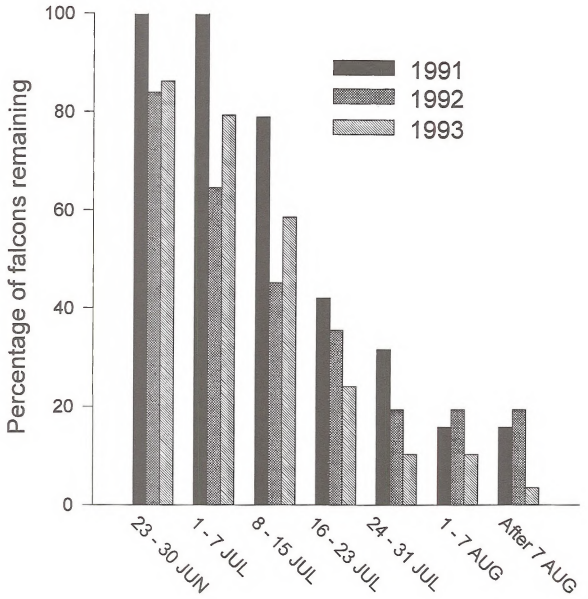


Fig. 22. Dispersal of radio-tagged falcons from the study area, 1991-93. We censused falcons from aircraft and from prominent receiver sites and recorded their presence or absence from the study area during the time intervals listed.

Behavior of Nesting Prairie Falcons

Attendance in the Territory and at the Nest.—As in 1991 and 1992, female falcons spent more of their time in their territories and close to their nests than did male falcons. When nestlings were <21 days old, females were observed in their territory an average of 77.6% of the time (n = 11, SD = 15.4), but males were observed in their territory only 29.0% of the time (n = 11, SD = 11.7). Females were in their territories an average of 43.8% of the time (n = 7, SD = 12.3) when nestlings were 21-40 days old, whereas males were in attendance 29.4% of the time (n = 7, SD = 8.3). When nestlings were <21 days old, females were seen within 5 m of the aerie 62.3% of the time (n = 11, SD = 15.2), and males were seen near the nest 9.0% of the time (n = 11, SD = 6.2). Both sexes reduced the time they spent at the nest as nestlings aged, but females still spent more of their time at the nest than did males (nestlings 21-40 days old: percentage of time female at nest = 11.6%, n = 7, SD = 10.3; for male = 4.3%, n = 7, SD = 2.6).

Parental attendance in the territory, based on visual observations, showed that parents nesting within the OTA shadow generally spent less time in their territories during the early and late brood-rearing periods than parents nesting west of the OTA (Fig. 23A). In 1991, a repeated measures ANOVA controlling for brood size and hatch date showed that as nestlings aged, males and females from OTA shadow nests, as well as females from nests west of the OTA, spent significantly less time in the territory. Males from nests west of the OTA spent more time in the territory as nestlings aged. Territory attendance was not significantly influenced by proximity of the aerie to the OTA in 1992. We tested for differences among all years and found that territory attendance was highest in 1992 and was relatively the same in 1991 and 1993 ($F_{2,22}$ = 7.09, P = 0.004). For all years combined, parents spent significantly more time in their territories west of the OTA than did parents in the OTA shadow ($F_{1,27}$ = 4.63, P = 0.043).

As in 1992, assessment of male attendance in the territory using radio telemetry from the observation blind confirmed our direct observations. While tending nestlings <21 days old in 1993, males nesting in the OTA shadow spent less time in radio contact than males nesting west of the OTA ($\bar{x}_{OTA}$ = 46.8%, n = 2, SD = 19.1; $\bar{x}_{west}$ = 58.6%, n = 4, SD = 9.8). This trend was also observed when nestlings were 21 - 40 days old ($\bar{x}_{OTA}$ = 46.1%, n = 1; $\bar{x}_{west}$ = 54.4%, n = 2, SD = 7.1). These mean percentages, although higher, mirror what we found by visually monitoring territory attendance. Males from OTA shadow nests spent slightly less time in the territory than did males from nests west of the OTA. Comparisons for females could not be made in 1993 because no observations were completed at sites with instrumented females in the OTA shadow.

Pooled data for 1991, 1992, and 1993 showed that neither parents nesting in the OTA shadow nor parents nesting west of the OTA spent consistently more or less time in their territories on training days versus non-training days (Table 7). Females nesting west of the OTA spent significantly more time at the nest on training days compared to non-training days ($F_{1,7}$ = 7.30, P = 0.03; Table 7).

During early and late brood rearing, males and females nesting west of the OTA shadow spent slightly more time tending their nestlings than did males and females nesting in the OTA shadow (Fig. 23B). However, this trend was not significant in a repeated measures ANOVA using 1991-93 data, and controlling for brood size and hatch date ($F_{0,27}$ = 0.28, P = 0.60; no significant covariates or interactions).

Parental attendance in the territory was not significantly correlated with the date of hatching in 1993 (Table 8); however, that most correlations were negative was consistent with findings in 1991-92. Combining data from 1991-93 produced significant results. As hatch date increased, females spent less time in the territory when nestlings were younger (r = -0.46, n = 39, P = 0.003) and when nestlings were older (r = -0.38, n = 34, P = 0.03), while males spent less time in the territory only when nestlings were older (r = -0.39, n = 34, P = 0.02).

Parents at nests where eggs hatched late in the season spent less time near the nest than parents at nests where eggs hatched earlier. In 1991 and 1993, the amount of time males spent tending older nestlings was negatively correlated with date of hatching. Females also exhibited this pattern but only in 1991 and 1992. Nest attendance for both males and females was negatively correlated with date of hatching when all 3 years were pooled (males: r = -0.51, n = 35, P = 0.002; females: r = -0.40, n = 35, P = 0.02).

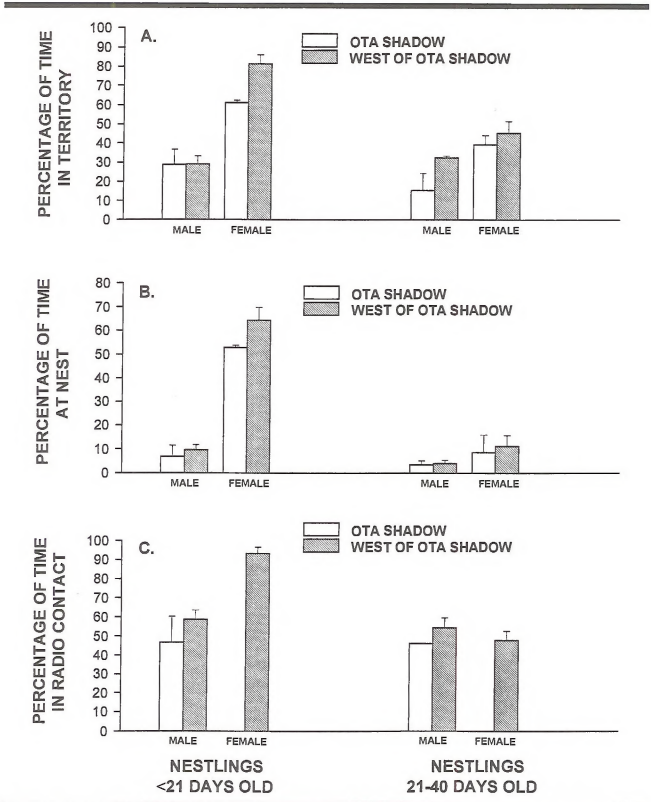


Fig. 23. Territory (A) and nest (B) attendance of prairie falcons nesting in the OTA shadow vs. nesting west of the OTA shadow, 1993. Percentage of time the radio-tagged member of the pair was in contact using an omni-directional antenna on the observation blind (C) is also plotted. Average behaviors (+ 1 SE) are presented separately for parents tending nestlings <21 days old and those tending 21-40 day old nestlings.

Table 7. Average differences in parental behavior at nests in the OTA shadow and west of the OTA on training versus non-training days in 1991-93. Observations were made within 1-5 days of each other at each nest once on training and once on non-training days. F-statistics are from repeated measure ANOVAs controlling for nestling age.

Parental Behavior	Average Differences in Parental Behavior (Training minus No Training) $\bar{x}$	n	SD	F	df	P
OTA NESTS						
Time (%) in territory						
Male	9.06	11	6.55	0.31	1,9	0.59
Female	14.19	11	11.05	0.53	1,9	0.49
Time (%) at nest						
Male	23.41	11	7.59	0.17	1,9	0.69
Female	9.27	11	11.52	1.49	1,9	0.25
Prey deliveries to nest/hr						
Male	0.13	14	0.12	2.69	1,12	0.13
Female	0.09	14	0.04	1.77	1,12	0.21
Total	0.18	14	0.14	3.53	1,12	0.09
Prey deliveries to territory/hr						
Male	0.16	6	0.12	1.66	1,4	0.27
Female	0.06	6	0.07	0.01	1,4	0.92
Total	0.18	6	0.05	1.37	1,4	0.31
Caches/hr						
Male	0.01	6	0.03			
Female	0.02	6	0.03	0.33	1,4	0.59
Total	0.03	6	0.11	0.16	1,4	0.71
WEST OF OTA NESTS						
Time (%) in territory						
Male	11.24	9	6.71	2.93	1,7	0.13
Female	8.86	9	9.68	4.36	1,7	0.08
Time (%) at nest						
Male	4.92	9	4.97	1.70	1,7	0.23
Female	6.68	9	8.04	7.30	1,7	0.03
Prey deliveries to nest/hr						
Male	0.22	9	0.12	0.02	1,7	0.89
Female	0.07	9	0.06	0.03	1,7	0.88
Total	0.18	9	0.12	0.01	1,7	0.92
Prey deliveries to territory/hr						
Male	0.17	8	0.16	0.82	1,6	0.40
Female	0.10	8	0.06	1.21	1,6	0.31
Total	0.21	8	0.17	0.12	1,6	0.74
Caches/hr						
Male	0.04	8	0.07	0.94	1,6	0.37
Female	0.07	8	0.05	0.01	1,6	0.95
Total	0.07	8	0.06	0.55	1,6	0.49

Parental attendance in the territory was not significantly correlated with brood size in 1993 (Table 8), but the slight negative relationships were consistent with findings in earlier years. Pooling data for all 3 years showed that parents spent more time at nests with large broods than at nests with small broods when nestlings were 21 - 40 days old (males: $r = 0.43$, $n = 34$, $P = 0.01$; females: $r = 0.39$, $n = 34$, $P = 0.02$).

In 1993, as in 1992, parental attendance declined as nestlings aged, regardless of where their nest was located. In 1993, females nesting west of the OTA and females nesting in the OTA shadow tended to spend less time in the territory and significantly less time at their nests as nestlings aged (Table 9, Fig. 23C). Males from nests west of the OTA and from nests in the OTA shadow did not decrease the amount of time they spent in the territory as nestlings aged. However, unlike males nesting in the OTA shadow, males nesting west of the OTA significantly decreased the time spent at the nest as nestlings aged (Table 9).

Table 8. Pearson correlations between hatching date, brood size, and parental behavior at all prairie falcon nests in the SRBOPA where intensive nest observation took place in 1993. Percentages were transformed prior to analysis (arcsine of square root).

PARENTAL BEHAVIOR	HATCHING DATE			BROOD SIZE		
	r	*n*	*P*	*r*	*n*	*P*
Percentage of Time in Territory						
Male (nestlings <21 days old)	0.11	11	0.74	-0.31	5	0.61
(nestlings 21-40 days old)	-0.42	8	0.30	-0.56	7	0.19
Female (nestlings <21 days old)	-0.33	11	0.32	0.68	5	0.27
(nestlings 21-40 days old)	-0.16	8	0.70	-0.04	7	0.94
Percentage of Time at Nest						
Male (nestlings <21 days old)	-0.12	11	0.72	0.31	5	0.61
(nestlings 21-40 days old)	-0.80	8	0.02	-0.22	7	0.64
Female (nestling <21 days old)	0.06	11	0.86	0.68	5	0.20
(nestlings 21-40 days old)	-0.33	8	0.43	0.12	7	0.79
Prey Deliveries to Nest per Hr						
Male (nestlings <21 days old)	-0.05	11	0.90	0.47	5	0.42
(nestlings 21-40 days old)	-0.79	9	0.01	0.17	8	0.69
Female (nestlings <21 days old)	-0.08	11	0.82	0.61	5	0.27
(nestlings 21-40 days old)	-0.28	9	0.46	-0.55	8	0.16
Total (nestlings <21 days old)	-0.08	11	0.81	0.69	5	0.20
(nestlings 21-40 days old)	-0.63	9	0.07	-0.22	8	0.61
Prey Deliveries to Territory per Hr						
Male (nestlings <21 days old)	-0.17	11	0.63	-0.58	5	0.37
(nestlings 21-40 days old)	-0.78	9	0.01	0.22	8	0.61
Female (nestlings <21 days old)	-0.16	11	0.65	-0.64	5	0.25
(nestlings 21-40 days old)	-0.27	9	0.48	-0.52	8	0.19
Total (nestlings <21 days old)	-0.21	11	0.54	0.20	5	0.75
(nestlings 21-40 days old)	-0.59	9	0.09	-0.21	8	0.63
Caches per Hr						
Male (nestlings <21 days old)	-0.44	11	0.18	0.79	5	0.11
(nestlings 21-40 days old)[a]		9			8	
Female (nestlings <21 days old)	-0.15	11	0.66	0.79	5	0.11
(nestlings 21-40 days old)	-0.51	9	0.17	-0.10	8	0.81

[a] no caching behavior was observed for males during this time period

Delivery of Prey Items.—Delivery of prey items to the nest and to the territory did not differ significantly among the 3 years of study (delivery to nest: $F_{(2,25)} = 0.76$, $P = 0.48$; delivery to the territory: $F_{(1,13)} = 0.56$, $P = 0.47$). However, 1993 stands in contrast to 1991 and 1992 because the average prey delivery rates declined, rather than increased, as nestlings aged (Table 9, Fig. 24). This difference was significant for deliveries to the nest, but not for deliveries to the territory (interaction between age and year: deliveries to nest: $F_{(2,23)} = 3.4$, $P = 0.05$; deliveries to territory: $F_{(1,13)} = 0.64$, $P = 0.44$). Differences in prey delivery rates were most striking for males (interaction between sex and year: deliveries to nest: $F_{(2,23)} = 3.1$, $P = 0.06$; deliveries to the territory: $F_{(1,13)} = 3.3$, $P = 0.09$).

In 1993, the average delivery rate of prey to nestlings was higher for males and females nesting in the OTA shadow than for males and females nesting west of the OTA, regardless of nestling age (Fig. 24A). As nestlings aged, prey deliveries decreased somewhat at the OTA shadow nests, but remained relatively constant at nests west of the OTA. Combining all 3 years yielded no difference in male and female prey delivery rates at nests west of the OTA and at nests in the OTA shadow ($F_{(1,29)} = 0.036$, $P = 0.56$). Age of nestlings, brood size, and sex of parent interacted significantly ($F_{(1,29)} = 5.80$, $P = 0.02$). Females increased their deliveries as brood size increased when nestlings were <21 days old ($r = 0.39$, $n = 34$, $P = 0.02$) but not when they were 21 - 40 days old ($r = 0.22$, $n = 37$, $P = 0.19$). Males in-

Table 9. Pearson correlations between age of prairie falcon nestlings (days) and parental behavior at nests inside the OTA shadow and west of the OTA shadow in 1993. Percentages were transformed prior to analysis (arcsine of square root).

	Nestling Age					
	OTA nests			West of OTA nests		
Parental Behavior	r	n	P	r	n	P
Time (%) in territory						
Male	-0.36	(9)	0.35	-0.10	(27)	0.63
Female	-0.64	(9)	0.06	-0.73	(27)	<0.001
Time (%) at nest						
Male	-0.29	(9)	0.46	-0.59	(27)	0.001
Female	-0.85	(9)	0.004	-0.92	(27)	<0.001
Prey deliveries to nest per hr						
Male	-0.29	(9)	0.45	-0.31	(27)	0.12
Female	0.35	(9)	0.36	0.11	(27)	0.59
Total	-0.17	(9)	0.66	-0.15	(27)	0.46
Prey deliveries to territory per hr						
Male	-0.28	(9)	0.47	-0.45	(27)	0.02
Female	0.32	(9)	0.40	0.34	(27)	0.09
Total	-0.08	(9)	0.83	-0.27	(27)	0.18
Caches per hr						
Male*		(9)	-0.35		(27)	0.07
Female	-0.29	(9)	0.46	-0.61	(27)	0.001
Total	-0.29	(9)	0.46	-0.68	(27)	<0.001

*no caching behavior was observed for males in the OTA

creased deliveries according to brood size only when nestlings were older ($r = 0.41$, $n = 37$, $P = 0.01$).

Fresh prey items delivered to the territory showed the same pattern as items delivered to the nest; parents in the OTA shadow delivered prey at a higher rate than parents west of the OTA, and all parents decreased their deliveries as nestlings aged (Fig. 24B).

In 1992, males west of the OTA and females in the OTA shadow had higher delivery rates than males in the OTA shadow and females west of the OTA, respectively, but rates did not differ significantly. Proximity of the OTA did not have a significant effect on the total of male and female deliveries to the territory for 1992 and 1993 data combined ($F_{(1,15)} = 0.001$, $P = 0.99$). Age of nestlings and brood size interacted significantly ($F_{(3,15)} = 5.34$, $P = 0.04$) because deliveries increased with increases in brood size when nestlings were 21 - 40 days old ($r = 0.36$, $n = 23$, $P = 0.09$) but not when they were <21 days old ($r = -0.09$, $n = 20$, $P = 0.72$).

Caching and retrieval rates in 1993 were higher at nests west of the OTA than at nests in the OTA shadow (Fig. 24C, D). In fact, males at OTA shadow nests were not observed caching or retrieving any prey during the brood-rearing period. Females from OTA shadow nests cached prey only when nestlings were younger (<21 days old) and were not observed retrieving prey during the nesting cycle. Females nesting west of the OTA shadow cached and retrieved items throughout the nesting cycle; males did not cache any prey when nestlings were 21 - 40 days old, but cached and retrieved prey at other times (Table 9). These differences paralleled those found in 1992, but an ANOVA using both years of data showed an interaction among age of nestlings, sex of parent, proximity to the OTA, and year for cache rate ($F_{(3,19)} = 4.08$, $P = 0.06$) and retrieval rate ($F_{(3,19)} = 7.62$, $P = 0.02$). However, because sample size was very small for the 1993 data and the same pattern of low cache and retrieval rates at sites in the OTA shadow versus high rates at sites west of the OTA was evident for both years, we pooled the data. Results

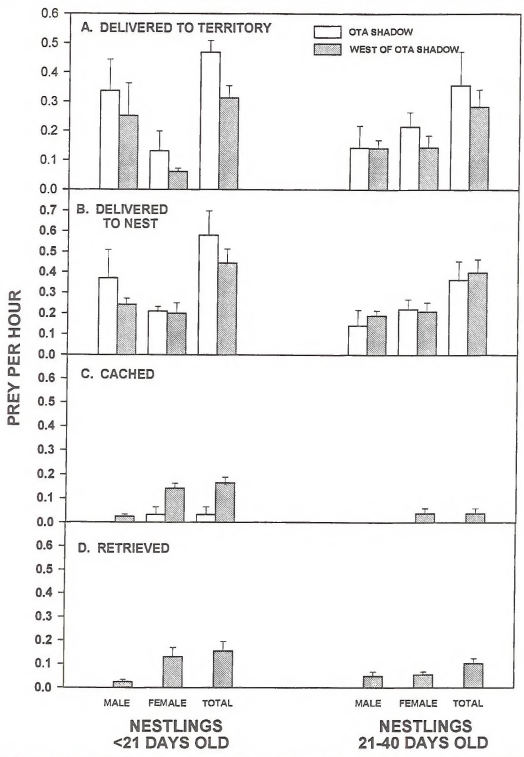


Fig. 24. Food handling behaviors by prairie falcons nesting in the OTA shadow vs. those nesting west of the OTA shadow, 1993. Delivery of fresh items into the territory (A), delivery of all items to the nestlings (B), caching (C) and retrieval (D) of all items are plotted as rates per hour of observation. Average behaviors (+1 SE) are presented separately for parents tending nestlings <21 days old and those tending 21-40 day old nestlings. Delivery of items into the territory are minimum rates because items not able to be classified as fresh or old are not included. Likewise, retrievals do not include items not known to be previously cached and are therefore minimum rates.

yielded a highly significant effect of proximity of nests to the OTA on caching and retrieval rates. Caching occurred more frequently at sites west of the OTA than at sites in the OTA ($F_{(1,15)} = 9.41$, $P = 0.008$). Cache retrieval was also seen more at nests west of the OTA than at nests in the OTA shadow ($F_{(1,15)} = 18.84$, $P = 0.001$). The OTA effect, however, depended upon the age of nestlings; parents west of the OTA reduced cache retrievals as their nestlings age, but those in the OTA shadow retrieved caches at a steady rate as their nestlings aged (2-way interaction: $F_{(1,15)} = 10.85$, $P = 0.005$).

Male and female prey delivery rates, deliveries to the territory, and caching rates at nests in the OTA shadow or at nests west of the OTA, were not significantly different on days when training occurred versus days when training did not occur on the ranges (Table 7).

Delivery of prey to nestlings by parents was not correlated with brood size in 1993 (Table 8). However, the tendency for parents to deliver more food items to large broods than to small ones, paralleled findings in previous years and resulted in a significant correlation for pooled data. When nestlings were <21 days old, females delivered more prey to larger broods than to small broods ($r = 0.39$, $n = 34$, $P = 0.02$). Larger broods of 21 - 40 day old nestlings received more prey than small broods (males: $r = 0.41$, $n = 37$, $P = 0.01$; total male and female: $r = 0.48$, $n = 37$, $P < 0.01$). Deliveries to the territory and caching rates were not significantly correlated with brood size in 1991, 1992, 1993, or when data were combined for all years.

In 1993, date of hatching was correlated with prey delivery rates for males with nestlings 21 - 40 days old (Table 8). The few significant correlations in 1993 indicated that, as in 1991, 1992, and when data were pooled, parents reduced their delivery rate at nests that hatched late in the season. Deliveries to the territory also showed this trend, but correlations were significant only in 1993 (Table 8) and when data were pooled for 21 - 40 day old nestlings (female rate: $r = -0.42$, $n = 25$, $P = 0.04$; total male and female rate: $r = -0.49$, $n = 25$, $P = 0.01$). Caching rate was not correlated with hatch date in 1993 (Table 8). However, hatch date was negatively correlated with the total of male and female caching rates during early brood rearing in 1992. Combined data for all years showed that the caching rate decreased as nestling hatching date occurred later in the breeding season (<21 day old nestlings: total male and female rate: $r = -0.41$, $n = 26$, $P = 0.04$; 21 - 40 day old nestlings: female rate: $r = -0.11$, $n = 24$, $P = 0.05$; total male and female rate: $r = -0.09$, $n = 24$, $P = 0.01$).

The prey items brought to nests in 1993 were more evenly distributed among prey types than in previous years (Fig. 25, Likelihood ratio test on categories, lumping kangaroo rats [*Dipodomys spp.*], birds and reptiles: $G^2_{(3)} = 83.6$, $P < 0.001$). The percentage of ground squirrels delivered to nestlings increased from 44% in 1991 to 59% in 1992, then dropped to 28% in 1993. Thirty percent of 244 prey items brought to nests west of the OTA were Townsend's ground squirrels, as were 25% of 85 items delivered to nestlings within the OTA shadow (Fig. 25). However, the percentage of unidentifiable prey items and mammals increased in 1993 relative to 1992. As in previous years, falcons nesting within the OTA shadow delivered a more even diet to their nestlings than parents nesting west of the OTA shadow (Likelihood ratio test on categories in Fig. 25 lumping kangaroo rats, birds and reptiles: $G^2_{(3)} = 21.2$, $P < 0.001$). Pooled data for all 3 years yielded a highly significant difference between the evenness of diets of falcons nesting in the OTA shadow and those nesting west of the shadow (Likelihood ratio test as above: $G^2_{(3)} = 21.4$, $P < 0.001$).

The bimodal pattern of prey deliveries evident in 1991 and 1992 was observed only for nests west of the OTA shadow in 1993. In contrast, prey deliveries to nests in the OTA shadow remained relatively low but constant throughout the day (Fig. 26B, F). This difference was not significant (Likelihood ratio test on categories in Fig. 26 lumping 0 - 1 hr after sunrise and 14 - 16 hrs after sunrise: $G^2_{(13)} = 4.53$, $P = 0.98$). Combining data for all 3 years also yielded no significant difference in the temporal distribution of prey delivered to nests in the OTA shadow versus nests west of the OTA ($G^2_{(13)} = 18.57$, $P = 0.14$). Delivery rates to the territory also showed a bimodal distribution with a peak in mid-morning and late afternoon for nests west of the OTA shadow and a constant rate to nests in the OTA shadow (Fig. 26A, E). For nests west of the OTA, delivery of prey items early in the morning to nestlings included cache retrievals as well as fresh prey items (Fig. 26F, G). Prey retrieved from caches was highest prior to the afternoon peak of fresh items delivered to

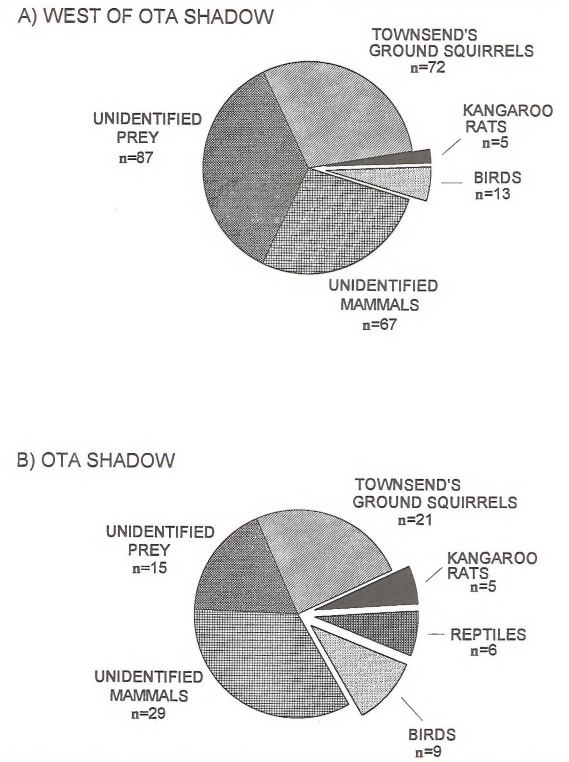


Fig. 25. Composition of prey items delivered to nestling prairie falcons in the OTA shadow compared to west of the OTA shadow, 1993. Positively Identified prey items are identified to genus or species. "Unidentified mammals" could be identified to class, but not to genus and "Unidentified prey" could not be identified to class: both groups may include Townsend's ground squirrels and kangaroo rats. Percentages are plotted as pieces of a pie totaling 100%. Actual number of prey in each grouping is listed as *n*.

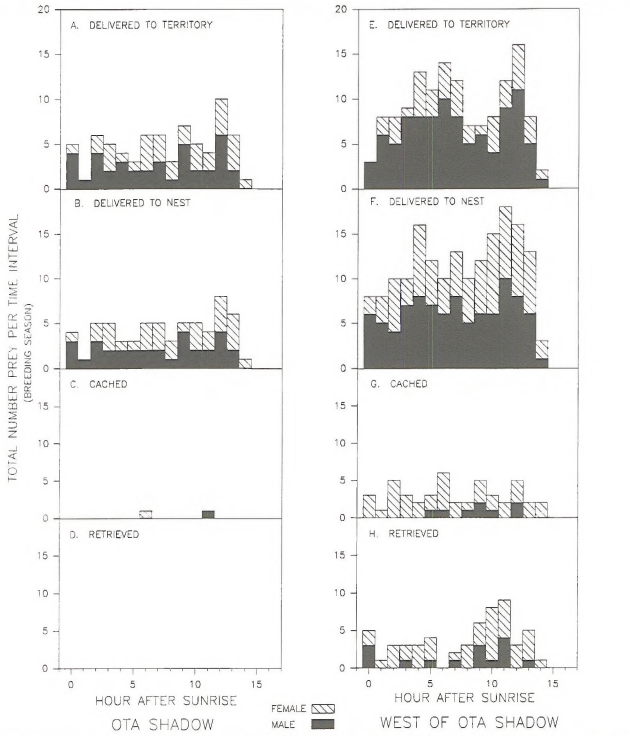


Fig. 26. Timing of the total number of prey items delivered to the territory and the nest, cached, and retrieved by adult prairie falcons during the 1993 breeding season. The total number of items plotted is sensitive to observation time and is not comparable between OTA shadow sites and west of OTA shadow sites. Relative differences throughout the day are comparable because each hour was observed the same number of times. Total prey items handled by falcons for each section of the figure are as follows: A) male n=39, female n=33, B) male n=32, female n=31, C) male n=0, female n=1, D) male n=0, female n=0, E) male n=97, female n=41, F) male n=93, female n=81, G) male n=8, female n=38, H) male n=0, female n=0.

nestlings (Fig. 26F, H). Only 2 prey items were cached, and no prey times were retrieved by parents nesting in the OTA shadow (Fig. 26C, D).

Influence of Behavior on Production of Fledglings.—In 1991, 1992, and 1993, parental attendance in the territory was not correlated with fledgling success. There were no significant correlations between parental attendance in the territory and the number of fledglings produced for all 3 years pooled (male attendance in territory during early brood-rearing: $r = 0.01$, $n = 33$, $P = 0.96$; late brood-rearing: $r = -0.18$, $n = 34$, $P = 0.30$; female attendance in territory during early brood-rearing: $r = 0.11$, $n = 33$, $P = 0.56$; late brood-rearing: $r = -0.13$, $n = 34$, $P = 0.46$). Attendance within 5 m of the nest was not correlated with the production of fledglings in 1992 or 1993 as it was in 1991.

Nest attendance during the late brood-rearing period was positively correlated with fledgling production when data from all years were pooled (male attendance: $r = 0.42$, $n = 35$, $P = 0.01$; female attendance: $r = 0.37$, $n = 35$, $P = 0.03$).

Military Training and Raptor Abundance

Military training was not consistent throughout the year or between years (Fig. 27A). In 1991, the numbers of raptors observed on the ranges decreased as the level of activity on the OTA increased ($r = -0.61$, $n = 31$, $P < 0.001$). There was a trend towards fewer raptors associated with increases in overall activity on the OTA in 1992 ($r = -0.24$, $n = 35$, $P = 0.16$), but no correlation in 1993 ($r = 0.05$, $n = 29$, $P = 0.76$).

Paired Observations at Ranges.—Our experiment using 4 tank and artillery ranges revealed no difference in the number of raptors observed on days when firing occurred versus days when firing did not occur, regardless of season (Fig. 28A, B, C; early season: $F_{(1,2)} = 0.19$, $P = 0.69$; mid-season: $F_{(1,2)} = 0.08$, $P = 0.81$; late season: $F_{(1,3)} = 0.51$, $P = 0.53$). As in previous years, mean abundances of raptors observed were not uniform throughout the season or throughout the day: raptors tended to be less abundant as the season progressed, regardless of military activity (Fig 28A, B, C; $F_{(2,1)} = 62.43$, $P = 0.09$).

The influence of temperature and wind speed on the abundance of raptors was not directly taken into account in the repeated measures analyses presented above. However, analyses of average temperature and wind speed throughout the day on firing and non-firing days suggests that, as in 1992 (Marzluff et al. 1992, Fig. 23), these factors did not confound our results. Temperatures increased throughout the day in all seasons ($F_{(3,6)} = 6.65$, $P < 0.001$), but the patterns of increase were similar on firing and non-firing days (interaction between military activity and time of day: $F_{(3,6)} = 6.3$, $P = 0.68$). Wind speeds also increased throughout the days on which we made our observations ($F_{(3,6)} = 7.8$, $P = 0.006$) but did not vary significantly on firing versus non-firing days (2-way interaction between military activity and time of day: $F_{(3,6)} = 22.70$, $P = 0.85$). These interactions are unlikely to account for the interaction between firing and time of day reported for raptor abundance because, although temperatures and wind speeds increased throughout the day, there was no associated upward or downward trend in raptor abundance during these days.

The influence of military activity varied among seasons and years. There was a differential effect of military activity throughout the seasons and throughout the day among the 3 years of the study (4-way interaction among season, military activity, time of day, and year: $F_{(12,60)} = 2.06$, $P = 0.034$). Overall, military effects were more evident late in the day than early in the day, more during the early and mid seasons than late in the season, and more in 1992 than in 1991 or 1993. Exceptions to these generalities contributed to the 4-way interaction. During the early season in 1993, effects of military activity were most evident later in the day, but they lessened later in the day in 1991, and were constant throughout the day in 1992 (Fig. 29A). In mid-season, there was a consistent negative influence of training throughout the day in 1993 but only late in the day in 1991 and 1992 (Fig. 29B). Late in the season, counts were similar throughout the day regardless of year (Fig. 29C).

Prairie falcon counts were not influenced by military effects in the same way as were counts of all raptors. The influence of military activity on prairie falcons did not vary among years (4-way interaction among season, military activity, time of day, and year: $F_{(12,60)} = 0.712$, $P = 0.681$; 3-way interaction among season, military activity, and year: $F_{(12,60)} = 0.712$, $P = 0.681$). Combining prairie falcon counts on ranges from 1991-93, we observed fewer prairie falcons per hour when there was training on the range than when there was

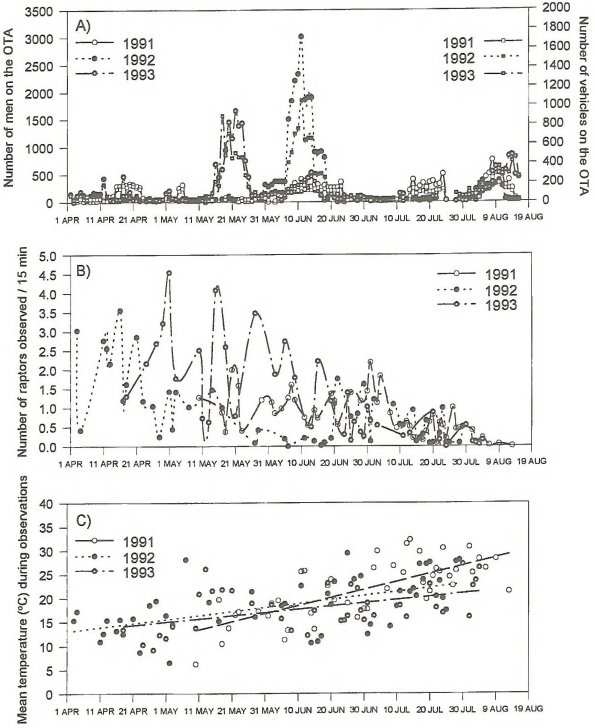


Fig. 27. Level of military activity (A) on the OTA, raptor abundance (B), and temperature (C) in 1991, 1992, and 1993. Relative intensity of military use of the OTA is represented by counts of men and vehicles on the OTA (A). Relative raptor abundance is plotted as the average number of raptors observed per 15 min on all ranges observed on a given day (B). Hourly temperatures were obtained from the National Weather Service, and averaged over the observation period (C).

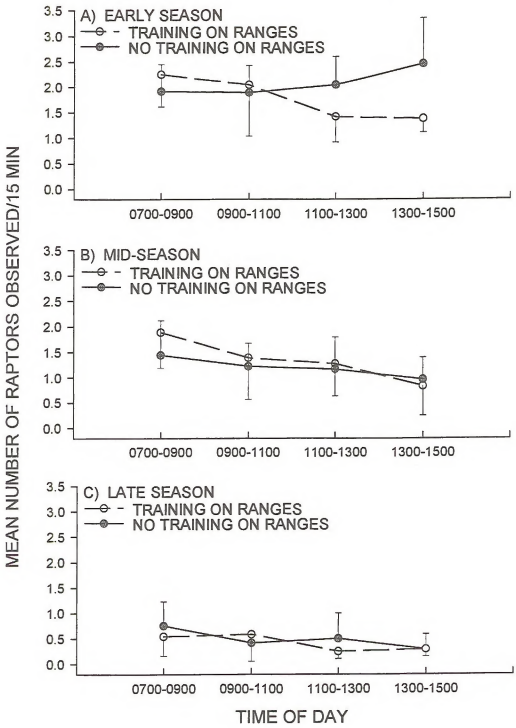


Fig. 28. Number of raptors observed on military tank firing and small arms firing ranges throughout the day in each of 3 seasons in 1993. Average +/- 1 SE are plotted for firing ranges versus non-firing ranges. Early season includes the first pair of observations made on each range and spans the period from 17 April - 17 May. Mid-season includes the second pair of observations made on each range and spans the period from 1 - 18 June. Late season includes the third pair of observations made on each range and spans the period from 30 June - 23 July.

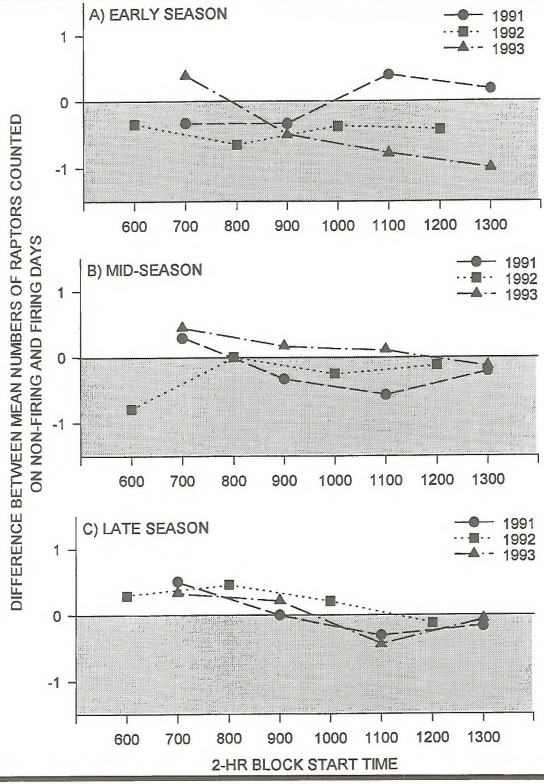


Fig. 29. Difference between mean numbers of raptors counted on tank firing, small arms firing, and artillery ranges throughout the day in each of 3 seasons in 1991-93. Portions of the lines that are in the shaded area indicate a military effect. Points on the line between the shaded and unshaded areas indicate no effect of military training. Portions of the lines that are out of the shaded area indicate an enhancement in the number of raptors observed when training occurred. The range of dates used for each season (A, B, C) is given in Fig. 28.

no training ($F_{(1,11)} = 6.23$, $P = 0.03$). However, there was no significant effect of firing on the numbers of prairie falcons observed within any season (Fig. 30; early season: $F_{(1,15)} = 2.78$, $P = 0.12$; mid-season: $F_{(1,16)} = 1.27$, $P = 0.28$; late season: $F_{(1,16)} = 0.45$, $P = 0.52$). Within the early season, prairie falcon counts varied among years ($F_{(2,15)} = 3.9$, $P = 0.043$). During mid-season and late season, counts did not differ among years (mid-season: $F_{(2,16)} = 1.34$, $P = 0.29$; late season: $F_{(2,16)} = 1.6$, $P = 0.23$).

Differences in counts of raptors observed between 1992 and 1993 were evident in the all-day observations we made on 1 range (range 10) throughout the day on firing and non-firing days (Fig. 31: 3-way interaction among year, season and time of day: $G^2_{(2)} = 45.34$, $P = 0.008$). Overall, counts were higher in 1993 in all seasons. The differences between seasons are the same as we reported for all ranges: more birds were observed earlier in the season than late in the season, and the influence of military training appeared to lessen late in the afternoon. On these days, maximum differences between firing and non-firing days occurred in the morning and midday, but more data are needed.

Observations at All Ranges.—Differences in raptor activity associated with all types of military activity at 8 ranges and 4 bivouac/maintenance sites in 1993 paralleled findings in 1991 and 1992 (Fig. 32A). However, differences were not significant in 1993 ($F_{(4,94)} = 0.81$, $P = 0.522$). Artillery training and tank training that involved firing (the main turret guns and/or the machine guns) were associated with the lowest levels of raptor activity (Fig. 32A). Tank training that did not involve live ammunition (preparation, driving, and/or laser training), firing of small arms, and convoy traffic on Range Road were associated with levels of raptor activity similar to activity when no training occurred. Likewise, there was no evident difference in raptor activity when we compared average activity on days with no training, "quiet" tank training, and Range Road traffic to activity on days with tank, mortar, or small arms firing ($F_{(3,97)} = 1.41$, $P = 0.23$). This effect of the type of military training was less in 1993 than in previous years, but the trends were in the same direction in all 3 years; therefore the combined analysis of 1991-93 was highly significant. Raptor abundance varied across all 6 categories of military activity ($F_{(4,423)} = 4.57$, $P = 0.001$) and was significantly lower during firing compared to non-firing activities ($F_{(1,426)} = 4.75$, $P = 0.03$).

Temperature was a significant covariate in all analyses of influence of military activity on numbers of raptors observed (1993: all military activity: $F_{(1,94)} = 7.74$, $P = 0.007$; lumped activity: $F_{(1,97)} = 7.84$, $P = 0.006$: 3 years: all military activity: $F_{(1,414)} = 38.5$, $P < 0.001$; lumped activity: $F_{(1,426)} = 43.38$, $P < 0.001$). Contrary to previous years, wind speed did not contribute to the explanation of raptor activity in 1993 (all military activity: $F_{(1,94)} = 0.364$, $P = 0.55$; lumped activity: $F_{(1,97)} = 0.32$, $P = 0.57$), although when data were combined, wind was a significant covariate in the analysis of firing versus non-firing activity ($F_{(1,426)} = 5.58$, $P = 0.009$).

The consistency of military activity during our samples of raptor abundance influenced the number of raptors observed. As in previous years, raptor activity on ranges was not constant during each of our samples. We counted more raptors when the range was completely or partially inactive and fewer when it was active throughout the survey, although unlike in 1991 and 1992, this effect was not significant in 1993 (Fig. 32B; $F_{(2,86)} = 1.12$, $P = 0.33$). However, because the trend was similar to our findings in 1991 and 1992, we combined the data from 1991-93, and analysis yielded a highly significant decrease in raptor abundance due to increased consistency of training ($F_{(9,421)} = 2.98$, $P = 0.002$). Temperature was a significant covariate in both analyses (1993: $F_{(1,94)} = 8.53$ $P = 0.004$; 1991-93: $F_{(1,421)} = 58.75$, $P < 0.001$). Wind speed was a significant covariate in the analyses of 1991-93 ($F_{(1,421)} = 5.8$, $P = 0.02$).

Military Training and Raptor Behavior.—Over 3 years of study, the 4 major groups of raptors using the training ranges exhibited species-typical repertoires of behavior in each year. Northern harriers (*Circus cyaneus*) spent most of their time in flapping and gliding flight low to the ground and often perched. Short-eared owls (*Asio flammeus*) and burrowing owls (*Speotyto cunicularia*) were rarely seen, but those that were observed rarely deviated from perching and flying low to the ground. Buteos (ferruginous hawks, golden eagles, rough-legged hawks [*Buteo lagopus*], red-tailed hawks [*B. jamaicensis*], Swainson's hawks [*B. swainsoni*]) soared more than any other group and often perched and flew low across the ranges. Falcons (prairie falcons, peregrine falcons [*Falco peregrinus*], and American kestrels [*F. sparverius*]) commonly used low flapping flight to traverse the area, but also often glided, soared, and perched.

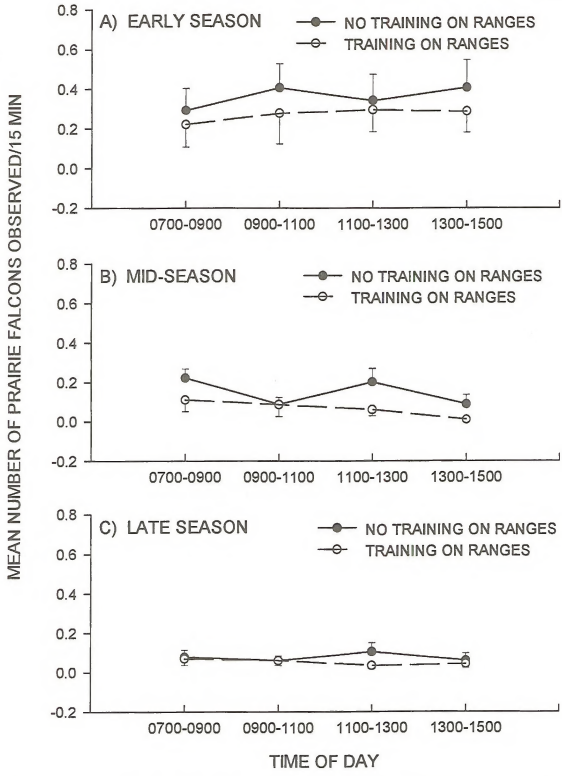


Fig. 30. Number of prairie falcons observed on tank firing and small arms firing ranges throughout the day in each of 3 seasons in 1993. Average +/- 1 SE are plotted when firing occurred on the range versus when no firing occurred. Seasons were described in the legend on Fig. 29.

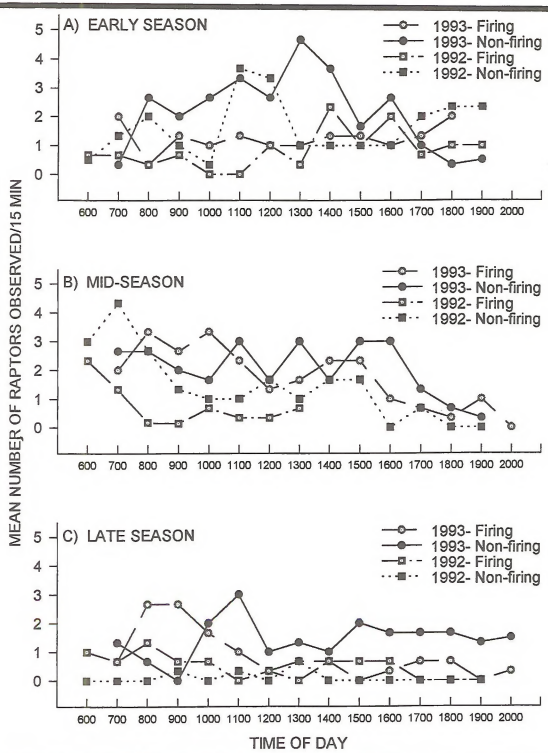


Fig. 31. Number of raptors observed during full-day observations at 1 tank training range (Range 10) during laser firing in each of 3 seasons in 1992 and 1993. Average +/- 1 SE are plotted when firing occurred on the range versus when no firing occurred. In 1992, early season observations were made on 6 and 13 May, mid-season observations were made on 25 and 28 June, late season observations were made on 16 and 24 July. In 1993, early season observations were made on 17 and 23 April, mid-season observations were made on 1 and 4 June, late season observations were made on 29 and 30 June. Data were unavailable for the evening session during mid-season on the firing day in 1992.

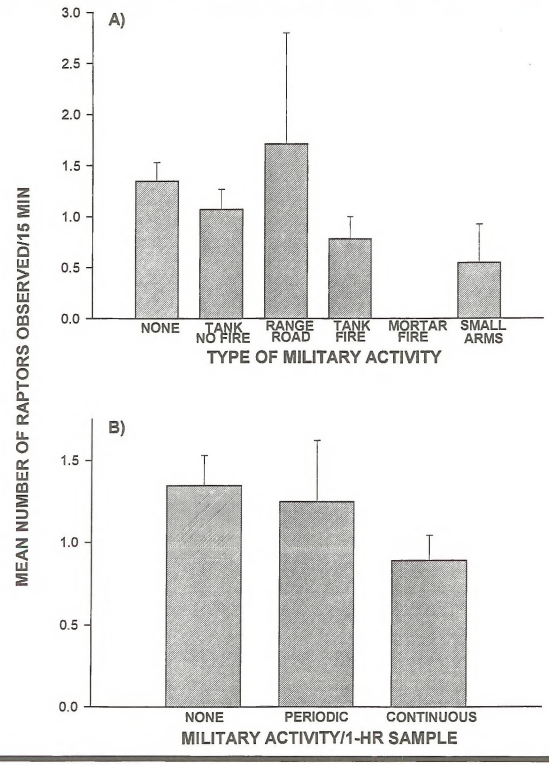


Fig. 32. Average number of raptors (+ 1 SE) observed on military firing ranges under different firing regimes in 1993. Type of military activity on the range (A) was categorized as: none = no activity, Tank/no fire = driving, preparing, laser-training tanks, range road = convoy traffic on the range road, tank/fire = tanks shooting main turret gun and / or machine guns, mortar fire = artillery firing, and small arms = M-60, M-16, M-40 rifle and 45 pistol firing. Military activity per hr (B) was categorized as none = no activity, partial = activity punctuated by periods of inactivity, and complete = sustained activity during entire hour. No mortar training was observed in 1993.

Visual inspection of Fig. 33 reveals similarities and differences in the way northern harriers, buteos, and falcons behaved on firing and non-firing days (compare N and T bars), and how each group utilized the area in versus out of the firing fan (compare shading in bars) in 1993. All groups tended to fly low and perch more on days without firing (N bars) and soar more on firing days (T bars). Northern harriers (Fig. 33A) and buteos (Fig. 33B) exhibited most behaviors out of the firing fan (open portion of bars). Falcons (Fig. 33C) exhibited a greater percentage of behaviors inside the fan, and attacked more often inside fans than outside of them.

The most stringent test of the hypothesis that raptor behavior was not influenced by military training is to compare behavior in versus out of the firing fan on firing versus non-firing days and determine how behaviors varies among the 3 years of the study. This is best tested by the 4-way interaction among behavior, location in or out of the fan, activity on the range, and year in log-linear models of 9 behavioral categories (Fig. 33 provides a description of categories).

Falcons behaved differently in and out of the firing fan in response to training activities in each year of study (4-way interaction among firing activity, location, behavior, and year: $G^2_{(8)} = 23.51$, $P = 0.036$; Table 10). Falcons generally perched and traveled at low heights (see PE, TF1 in Fig. 34) more in versus out of the fan and more on non-firing than firing days. Falcons traveled at the greatest heights (TF3) and spent most of their time soaring, maneuvering, and attacking (SF2, SF3, MAN, AT) on firing days inside the fan (Fig. 34). However, the degree of these responses varied between years (Fig. 34). Frequencies of common behaviors (PE, TF1, TF2, SF2, SF3 in Fig. 34) varied with respect to firing in the different years (3-way interaction among firing activity, behavior and year: $G^2_{(16)} = 33.47$, $P = 0.008$), but the frequencies did not change with respect to location (percent of shading within bars is similar in Fig. 34, 3-way interaction between location, behavior, and year: $G^2_{(16)} = 11.52$, $P = 0.8$). During 1991 and 1992, falcons tended to perform most behaviors without regard to location on the range although these behaviors were performed more often on non-firing days than on firing days (2-way interaction between firing activity and behavior: 1991: $G^2_{(8)} = 15.56$, $P = 0.05$; 1992: $G^2_{(8)} = 19.4$, $P = 0.014$).

Northern harriers behaved differently depending upon their location with respect to the firing fan in each year (Fig. 35), but not as a response to military activity (Table 10). In 1992, the most common behaviors of northern harriers (PE, TF1 in Fig. 35) were observed more frequently out of the firing fan, whereas in 1991 and 1993, perching (PE) was more often observed in the firing fan, and low flights (TF1) were more equally distributed between the locations (3-way interaction among location, behavior, and year: $G^2_{(7)} = 30.8$, $P = 0.02$). In 1991, northern harriers varied their behavior depending on whether there was firing activity as well as whether they were in or out of the firing fan (2-way interaction between firing activity and behavior: $G^2_{(8)} = 17.61$, $P = 0.02$; 2-way interaction between location and behavior: $G^2_{(8)} = 17.4$, $P = 0.03$). In 1992, northern harriers showed less variation in their use of behaviors with respect to activity on the ranges, but they used most behaviors more often outside of the firing fan (2-way interaction between location and behavior: $G^2_{(8)} = 21.93$, $P = 0.005$). In 1993, northern harriers exhibited behaviors in or out of the fan without regard to firing activity. Interestingly, most behaviors exhibited more often during firing in 1992 were exhibited less often during firing in 1993.

Table 10. Tests of the 3-way interaction among behavior, firing activity on the range, and location on the range for northern harriers, buteos and falcons in theOTA in 1991, 1992, and 1993. Sample sizes for owls were too small for analysis.

	1991			1992			1993		
	df	G^2	P	df	G^2	P	df	G^2	P
Northern harriers	8	7.94	0.44	5	7.68	0.18	8	3.95	0.86
Buteos	8	11.35	0.18	8	16.32	0.21	8	12.73	0.12
Falcons	8	14.72	0.07	8	7.14	0.52	8	24.18	0.002

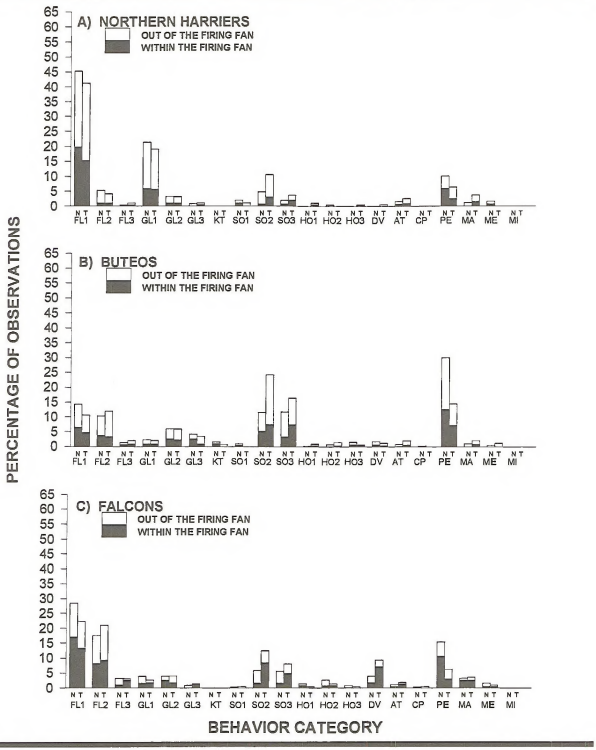

A) NORTHERN HARRIERS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
B) BUTEOS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
C) FALCONS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
PERCENTAGE OF OBSERVATIONS
BEHAVIOR CATEGORY
N T FL1 FL2 FL3 GL1 GL2 GL3 KT SO1 SO2 SO3 HO1 HO2 HO3 DV AT CP PE MA ME MI

Fig. 33. Full repertoire of behaviors recorded for 3 groups of raptors utilizing the military firing ranges in 1993. Percentage use of each behavior is compared on non-training days (N) and training days (T). Within each bar we show the percentage of each behavior recorded inside the firing fan relative to outside of the firing fan. Behavior codes are either a behavior or a combination of a behavior and a height code (1: 0-10 m, 2: 10-30 m, 3: >30 m) and are defined as follows: FL- flapping flight, GL- gliding flight, KT- kiting, SO- soar, DV- dive, HO- hover, PE- perch, AT- attack, PR- preen, MA- intraspecific maneuver, ME- interspecific maneuver, MI- individual maneuver, AT- attack, CP- carry prey.

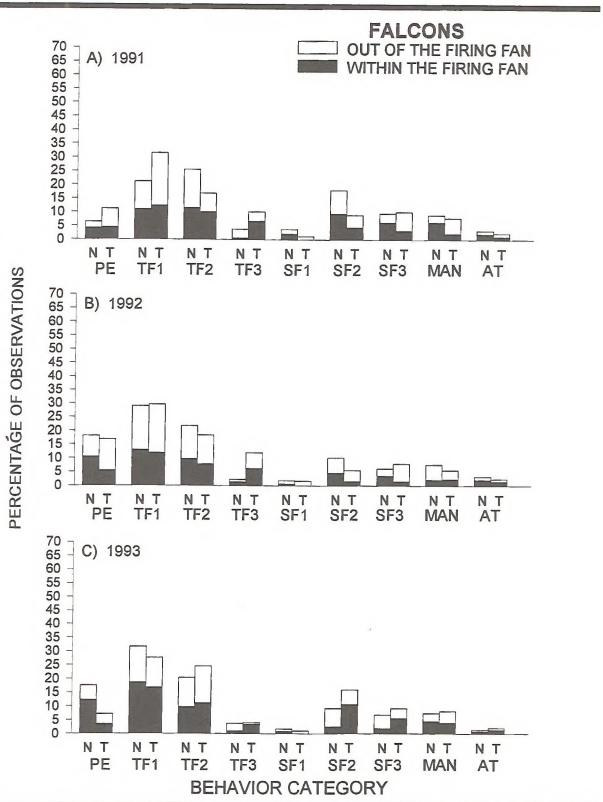


Fig. 34. Condensed repertoire of behaviors recorded for falcons utilizing the military firing ranges in 1991-93. Behavior codes are either a behavior or a combination of a behavior and a height code (1: 0-10 m, 2: 10-30 m, 3: >30 m) and are defined by combining codes in Fig. 33 as follows: TF. = FL, GL; SF = SO, KT, HO; MAN = DV that were not associated with an attack MA, ME, MI; AT = DV associated with an attack; PE = PE, PR.

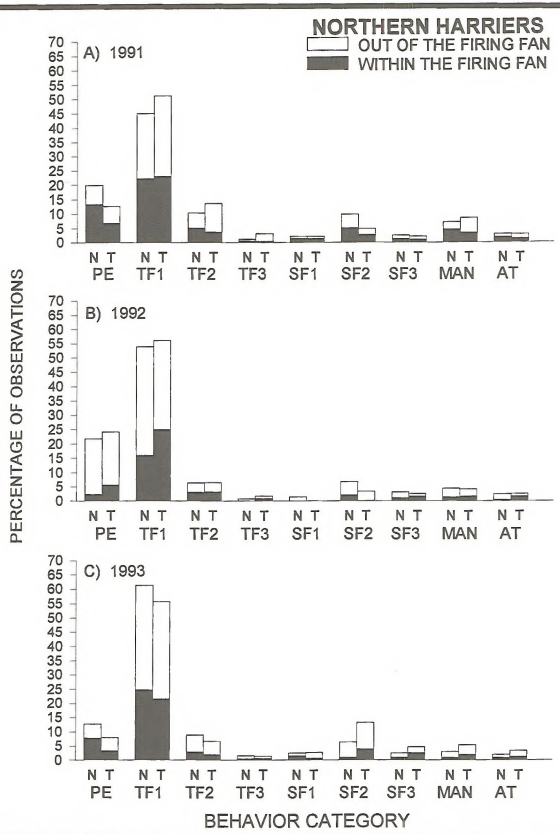

NORTHERN HARRIERS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
A) 1991
B) 1992
C) 1993
PERCENTAGE OF OBSERVATIONS
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70
N T
PE TF1 TF2 TF3 SF1 SF2 SF3 MAN AT
BEHAVIOR CATEGORY

Fig. 35. Condensed repertoire of behaviors recorded for northern harriers utilizing the military firing ranges in 1991-93. Behavior codes are either a behavior or a combination of a behavior and a height code and are defined in Fig. 34.

Buteos responded to training activities in and out of the firing fan differently among years (4-way interaction among firing activity, location, behavior, and year: $G^2_{(6)} = 27.25$, $P = 0.039$). Within any year, however, buteo behaviors in the firing fans were not influenced by firing activity (Table 10). Variation in buteo behavior depended more on the firing activity than on the location of the bird with respect to the firing fan. Like falcons, buteos varied their use of common behaviors depending on firing in each year (3-way interaction among firing activity, behavior, and year: $G^2_{(16)} = 70.78$, $P < 0.005$), but use of behaviors did not change with respect to location (percent of shading within bars is similar in Fig. 36; 3-way interaction among location, behavior, and year: $G^2_{(16)} = 22.4$, $P = 0.15$). Buteos also showed variation in their behaviors with respect to activity on the ranges between years (Fig. 36). In 1991, buteos exhibited similar frequencies of most behaviors on firing and non-firing days. However, most behaviors were observed more often outside of the firing fan (2-way interaction between location and behavior: $G^2_{(8)} = 21.84$, $P = 0.005$). In 1992, buteo behavior depended on whether there was firing activity, and most behaviors were observed more often out of the firing fan than in the firing fan (2-way interaction between firing activity and behavior: $G^2_{(8)} = 44.03$, $P < 0.001$; 2-way interaction between location and behavior: $G^2_{(8)} = 16.94$, $P = 0.04$). In 1993, buteos perched more and flew low (TF1) on non-firing days and soared high, maneuvered and attacked (SF2, SF3, MA, AT) more on firing days, without regard to position on the range (2-way interaction between firing activity and behavior: $G^2_{(8)} = 52.2$, $P < 0.001$). Analyzing only observations of ferruginous hawks for 1991-93 reveals that ferruginous hawks behaved similarly to northern harriers, another bench nester. Behaviors exhibited by ferruginous hawks depended more on location on the range than on firing activity (2-way interaction between location and behavior: $G^2_{(8)} = 22.46$, $P = 0.02$; 2-way interaction between firing activity and behavior: $G^2_{(16)} = 22.72$, $P = 0.12$).

The occurrence and fate of prey capture attempts did not depend upon military training activities. In 1993, we observed 52 attempts to capture prey by raptors on training ranges; 11 (21.2%) were successful, 32 (61.5%) were unsuccessful, and the fates of 9 (17.3%) were not determined. Attempts occurred on training versus non-training days and in versus out of the firing fan with similar frequency in 1993 ($X^2_{(1)} = 4.46$, $P = 0.35$), and in the combined sample of 250 attacks from 1991-93 ($X^2_{(1)} = 0.003$, $P = 0.96$). Furthermore, success rate did not differ with respect to military training or location of the attempt relative to the firing fan (3-way contingency table comparing success versus failure, in versus out of the fan, and on hot versus cold days: $X^2 = 0.33$, $P = 0.86$ (1993); $X^2 = 1.5$, $P = 0.22$ (1991-93)).

The average attack rate per hour on ranges tended to be lower on days with military firing than on days without firing. Attacks per hour averaged 0.16 ($n = 15$ ranges, SD = 0.16) on non-firing days, but only 0.10 ($n = 15$ ranges, SD = 0.09) on firing days ($F_{(1,14)} = 16.37$, $P = 0.001$). The ratio of successful to unsuccessful attempts did not differ on firing versus non-firing days during the 3 years of the study (2-way interaction between success and firing: multivariate $F_{(3,12)} = 0.38$, $P = 0.77$).

Point Counts in Maneuver Areas.—We obtained 4 paired samples of training versus no training in maneuver areas in 1993. There was no difference in the number of raptors observed per hr on training days versus non-training days ($\bar{x}$ difference = 0.005, $n = 31$, SD = 1.31; $F_{(1,2)} = 5.45$, $P = 0.15$). Similarly, we found no difference in numbers of raptors observed per hr in the morning versus in the afternoon on non-training versus training days ($\bar{x}$ difference in the morning = -0.03, $n = 15$, SD = 1.47, $\bar{x}$ difference in the afternoon = 0.04, $n = 16$, SD = 1.19; $F_{(1,2)} = 0.048$, $P = 0.85$).

Observations at the Construction Site.—Construction activities influenced the numbers of raptors observed in proximity to the disturbance. During the period of construction, we counted 1.8 ($n = 40$, SD = 0.24) raptors per hour on days when there was construction activity and 3.2 ($n = 8$, SD = 1.68) raptors per hour when there was no construction during the observation day ($F_{(1,29)} = 4.3$, $P = 0.05$). Raptor counts were higher in this area due to the presence of an occupied burrowing owl nest.

Golden Eagles

Trapping.—We trapped at only 1 of the 2 additional territories selected for 1993 (Ogden) due to time constraints and the unexpected addition of a new territory (Pole 369) when the Grand View Sand Cliff pair of instrumented eagles separated and both secured new mates. We trapped at all 3 original territories with instrumented females, at-

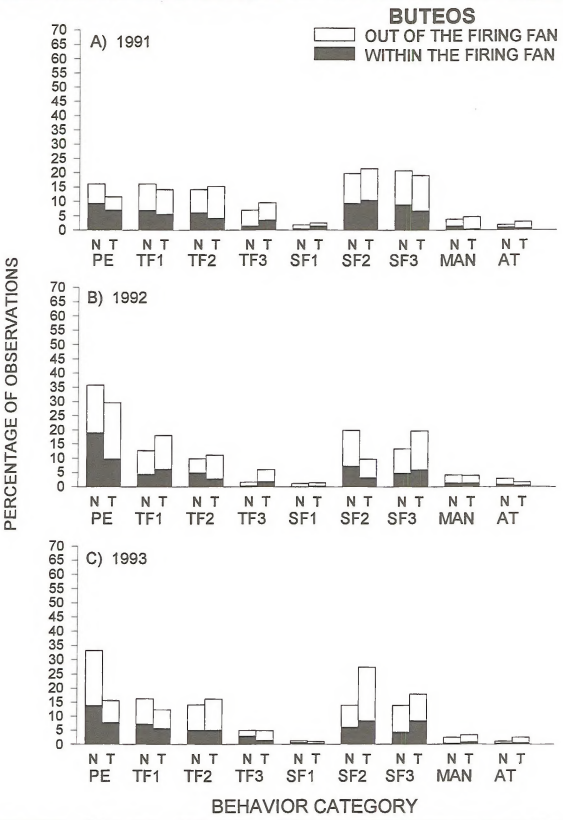


Fig. 36. Condensed repertoire of behaviors recorded for buteos utilizing the military firing ranges in 1991-93. Behavior codes are either a behavior or a combination of a behavior and a height code and are defined in Fig. 34.

tempting to capture males. We captured a total of 9 eagles, 4 of which were target breeding adults (see Appendix B for physical characteristics and Appendix C for trapping summaries). Three of the non-target captures were subadults (all with extensive white in their rectrices): 1 was a fledgling banded as a nestling at the territory in which it was captured, and 1 was an adult bald eagle (*Haliaeetus leucocephalus*). We failed to capture a target breeding adult at Cabin, but did capture the breeding female at the PP&L 119 territory. We captured 3 other breeding males at the Ogden, Wildhorse, and Grand View Sand Cliff territories. The previously instrumented Grand View Sand Cliff female subsequently moved to Pole 369 territory. This territory had been unsuccessful for the past 8 years. Both the Grand View Sand Cliff male and the Pole 369 female replaced their mates, and although both bred, only the instrumented female with her new mate at Pole 369 bred successfully.

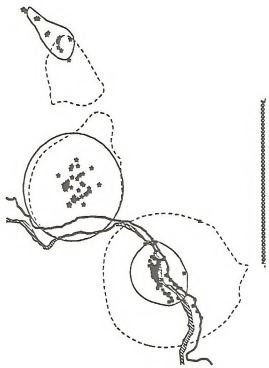
We captured 5 golden eagles wintering in the OTA during January 1993. Three of the individuals captured in the OTA were adults, and 2 were subadults (see Marzluff et al. 1992, for description of age classes).

Influence of Telemetry Packages.—In 1992 there were no significant differences in productivity between instrumented and control pairs. In 1992, 3 of 7 pairs with a radio-tagged member successfully fledged ≥1 nestling, compared to 10 of 19 control pairs ($G^2_{(1)} = 0.19$, $P = 0.66$). The number of young fledged per pair did not differ significantly ($F_{(1,24)} = 0.04$, $P = 0.85$) between instrumented ($\bar{x} = 0.86$, SE = 0.39, $n = 7$) and control pairs ($\bar{x} = 0.95$, SE = 0.24, $n = 19$). In 1993 we detected significant differences between instrumented and control pairs. Two of 9 instrumented pairs were successful compared to 13 of 18 control pairs ($G^2_{(1)} = 6.29$, $P = 0.01$) and the number of young fledged per pair by instrumented pairs ($\bar{x} = 0.22$, SE = 0.26, $n = 9$) was significantly lower ($F_{(1,25)} = 10.23$, $P = 0.004$) than the number fledged by control pairs ($\bar{x} = 1.22$, SE = 0.18, $n = 18$). For the analysis of 1992-93 combined data, we used a log-linear model to test for the interaction of treatment (instrumented or control) and year. This analysis showed that the interaction between treatment and success was the most significant contributor to the model ($G^2_{(1)} = 4.52$, $P < 0.05$). Because this model did not include productivity data for territories for which we lacked data from either year (the 2 new territories with radio-tagged individuals and 1 control territory for which success was not determined in 1993), we used logistic regression (with probability of success as a covariate) to analyze the complete data set. There were no significant interactions, but the 2-way interaction between year and treatment approached significance ($G^2_{(1)} = 6.8$, $P < 0.1$). Probability of success was not a significant covariate in the analysis ($G^2_{(1)} = 0.23$, $P > 0.50$). Instrumenting an eagle resulted in a significant decrease in the probability of nesting success, particularly during the 1993 breeding season. A 2-factor ANOVA (year and radio-tagging) of the number of young fledged in 1992-93 indicated a significant decrease due to radio-tagging ($F_{(1,49)} = 3.97$, $P = 0.05$) with a tendency towards an interaction between treatment and year ($F_{(1,49)} = 2.77$, $P = 0.103$).

Spatial Use Patterns of Territorial Eagles.—As in 1992, home ranges of eagles were centered around the nest, but size and shape were extremely variable (Figs. 37-42; Tables 11, 12). Ninety-five percent harmonic mean home range size varied from 930 ha to 51,432 ha, with ranges following a pattern similar to those in 1992; individuals having small ranges had small ranges and large ranges were again large. One exception was the Beecham territory which, although moderately sized in 1992, decreased by 79% in 1993.

Habitat composition of territories was weakly correlated with home range size. Data are currently available only for the portions of home ranges north of the Snake River. Home range size in 1993 was correlated with percentage of the area north of the river covered with sagebrush of medium density ($r = -0.57$, $n = 10$, $P = 0.085$). Territories with small amounts of sage were large. This relationship will likely strengthen when habitats south of the river are included because the small Cabin territory has little sage cover north of the river, but abundant sage south of the river. Approximately half of the variation in home range size can be accounted for by a multiple regression model using percentage of the range that was burned, covered with medium density sage, and covered with medium density shadscale ($R^2 = 0.51$; $F_{3,6)} = 2.1$, $P = 0.20$). Ranges with few burns, abundant sage, and abundant shadscale were largest.

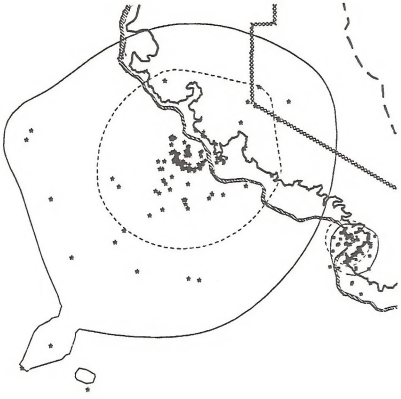
There was no consistent pattern of change in home range size from 1992 to 1993. The Beecham home range decreased by the largest amount, the



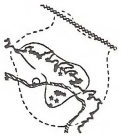
FEMALE-PPL 119, MALE-BEECHAM

MALE-OGDEN

Fig. 37. Home ranges for adult golden eagles throughout the 1992-93 season. Unique locations used by each eagle on each day of observation and the 95% harmonic mean range are plotted for the female from PPL 119 (bimodal range; stars indicate locations) and the male from Beecham (squares) in the upper portion of the figure, and for the male from Ogden in the lower portion. Dotted-lines indicate 95% harmonic mean home ranges for 1991-92. Solid lines indicate the 1992-93 home range. The Snake River (hatched area), canyon rim (thin solid line along river), OTA boundary (connected squares) and study area boundary (thick solid line) are included for orientation. All ranges are drawn to the same scale (1:235,294) and oriented with north at the top of the page unless otherwise noted.



FEMALE-WILDHORSE, MALE-BLACK BUTTE



FEMALE-CABIN

Fig. 38. Home ranges for adult golden eagles throughout the 1992-93 season. Unique locations used by each eagle on each day of observation and the 95% harmonic mean range are plotted for the female from Wildhorse (stars) and the male from Black Butte (squares) in the upper portion of the figure and the female from Cabin in the lower portion. Landmarks and dotted-lines are represented as in Fig. 37 with the addition of the range road (alternating solid and open line). All ranges are drawn to the same scale (1:200,000).

Table 11. Home range characteristics of paired golden eagles determined from radiotelemetry in 1992-93.

Nesting[a] Area	Sex	Burn	N	Mean distance from:[b]				Max distance from:[b]			Harmonic Mean Home Range[c]				Harmonic Mean Home Range Shape[d]				
				Nest	Hc	Ac	Hc-Nest	Nest	Hc	Ac	Max	95%	90%	50%	Hr	D	Sk	K	Sp
Brcs	M	Y	137	4,440	63	2,299	3,175	10,960	8,956	8,898	19,164	5,147	2,315	744	63.9	7.7	124.2	78.5	656
BlkBt	M	Y	122	854	83	853	955	4,563	4,512	4,236	2,122	930	593	130	84.1	7.7	63.1	32.6	356
Cabin	F	Y	30	2,071	172	1,758	2,996	4,804	3,397	3,181	1,688	900	476	115	179.9	3.4	29.0	13.4	698
GVSC	B	N	139	4,131	99	5,137	630	27,990	27,800	5,137	94,778	55,407	30,416	1,039	100.6	8.5	277.0	50.1	593
GVSC	M	N	111	4,799	88	5,963	323	27,990	27,960	24,500	89,355	51,432	37,033	851	89.6	8.5	29.0	13.4	698
WildH	F	N	47	5,138	947	4,618	1,481	26,800	26,650	22,780	68,520	39,441	21,629	1,354	988.8	3.9	16.8	8.7	2,195
WildH	M	N	32	4,860	711	3,623	1,536	18,330	16,930	14,110	23,649	16,029	9,331	1,394	757.5	2.0	8.7	5.4	2,022
WildH	B	N	77	4,961	69	4,162	1,536	26,800	25,320	22,670	85,264	22,542	16,653	1,357	70.7	8.0	307.6	21.7	192
Beech	M	Y	115	638	61	652	70	4,563	4,512	4,236	2,972	1,151	535	27	62.5	5.8	28.1	23.4	250
PL119	F	N	61	3,603	12	4,011	631	13,600	13,600	10,320	5,343	4,730	3,165	263	13.0	3.2	834.1	20.3	82
Ogden	M	N	61	2,853	44	2,364	2,585	7,355	5,489	5,634	7,094	3,333	2,790	630	44.8	5.9	74.0	52.6	398
P369	F	N	48	1,287	11	945	0	3,862	3,862	2,876	1,684	1,345	707	72	11.7	3.2	301.6	26.6	96

[a] Nesting areas are abbreviated as follows: Brcs - Beercase, BlkBt - Black Butte, GVSC - Grand View Sand Cliff, WildH - Wild Horse, Beech - Beecham, PL119 - PP&L 119.

[b] Distance expressed in m, abbreviated as follows: Hc - harmonic center, Ac - arithmetic activity center.

[c] Home ranges expressed in ha.

[d] Hr - sum of the reciprocal distance (d^{-1}) to each fix, divided by the number (n) of distances and then re-inverted (i.e., $n/\sum d^{-1}$), D - dispersion, Sk - skewness, K - kurtosis, Sp - spread.

Beercase home range decreased by 25%, and PP&L 119 home range decreased by <1%. The female at PP&L 119 territory exhibited the same bimodal use area that was evident for the male in 1992. The Grand View Sand Cliff and Wildhorse home ranges, which were the largest in 1992, increased by 342% and 87%, respectively. Black Butte was the smallest home range in 1992 and continued to be so in 1993, although it increased by 16%. The Cabin home range decreased, but we collected very few observations due to a malfunctioning transmitter. The new territorial eagles at the Ogden and Pole 369 territories had small home ranges, similar in size to Beecham and Black Butte.

Core use areas for all territories where we conducted observations in 1992 were nearly identical to those in 1993, even when a new nest was used. Territories with different nest locations included Beecham, Black Butte, Cabin, Grand View Sand Cliff and Wildhorse. Overlap of 1992 ranges on 1993 ranges (Figs. 37 - 40) was 100% for Grand View Sand Cliff and Wildhorse, the 2 territories that increased, and overlap of 1993 ranges on 1992 ranges was 100% for 3 of the territories that decreased. The remaining 2 territories, PP&L 119 and Black Butte, both showed <100% overlap for either year. PP&L 119 used the same 2 core areas, but slightly expanded use of the core area near the nest and shifted the northern core area to the northwest, away from a previously used area containing a newly constructed house. The male at the Black Butte territory expanded his core use area in 1993, but shifted it farther south along the canyon.

Male (n = 6) and female (n = 4) eagles did not show consistent differences in travel distances or home range size (Tables 11, 12). Travel distances to unique daily locations from the nest for males averaged 3,072 m (SD = 1,755), whereas females averaged 2,186 m (SD = 583). Maximum travel distances averaged 11,581 m (SD = 9,791) and 12,510 m (SD = 10,386) for males and females, respectively. The 95% harmonic mean and maximum polygon home ranges for males averaged 14,241 ha (SD = 19,468) and 11,159 ha (SD = 15,305), whereas the same measures of home range for females averaged 19,086 ha (SD = 33,337) and 7,793 ha (SD = 11,826). Mean home range size and maximum travel distances were generally larger in 1993 than in 1992 for both males and females, but the values for both sexes were influenced by the long distance excursions of a few eagles. Both of the Wildhorse eagles made long excursive flights to the mountains in the south, and the Grand View Sand Cliff male ranged widely away from the center of his territory.

Table 12. Home range characteristics of paired golden eagles determined from radiotelemetry, 1992-93.

Nesting[a] Area	Sex[b]	Burn	N	Convex Polygon Home Range				Maximum Polygon width(m)
				Max[c]	90%	70%	50%	
Brcs	M	Y	137	9,089	4,390	2,665	741	13,990
BlkBt	M	Y	122	4,800	525	276	121	4,800
Cabin	F	Y	30	1,112	696	599	217	5,110
GVSC	B	N	139	42,000	10,300	852	171	29,370
GVSC	M	N	111	41,100	13,000	1,195	160	29,370
WildH	F	N	47	25,470	7,992	1,344	619	32,720
WildH	M	N	32	11,550	3,679	1,611	834	18,610
WildH	B	N	77	25,470	8,537	2,453	768	32,720
Beech	M	Y	115	799	243	33	12	6,380
PL119	F	N	61	3,294	2,461	423	136	13,880
Ogden	M	N	61	3,385	2,486	1,676	692	10,200
P369	F	N	48	1,296	536	139	94	5,076

[a] Nesting areas are abbreviated as follows: Brcs - Beercase, BlkBt - Black Butte, GVSC - Grand View Sand Cliff, WildH - Wildhorse, Beech - Beecham, PL119 - PP&L 119.
[b] M = Male; F = Female; B = Both
[c] Home ranges expressed in ha.

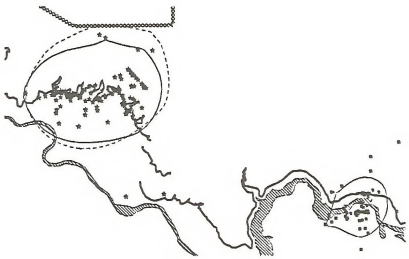


Fig. 39. Home ranges for adult golden eagles throughout the 1992-93 season. Unique locations used by each eagle on each day of observation and the 95% harmonic mean range are plotted for the male from Beercase (stars) and the female from Pole 369 (squares). Landmarks and dotted-lines are represented as in Fig. 37. All ranges are drawn to the same scale (1:200,000).

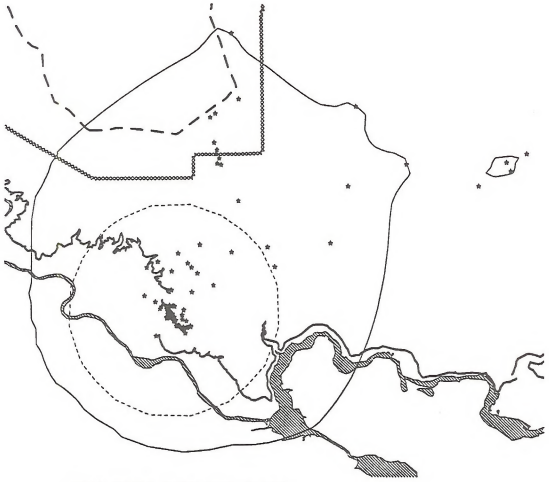


Fig. 40. Home ranges for adult golden eagle throughout the 1992-93 season. Unique locations used by each eagle on each day of observation and the 95% harmonic mean range are plotted for the male from Grand View Sand Cliff. This territory is adjacent to the southeast portion of the Beercase territory shown in Figs. 37 and 38. All ranges are drawn to the same scale (1:200,000).

Fig. 41. Home ranges of all eagles studied. Harmonic mean 95% ranges are plotted. Landmarks are represented as described in Figs. 37 and 38. All ranges are drawn to the same scale (1:300,000).

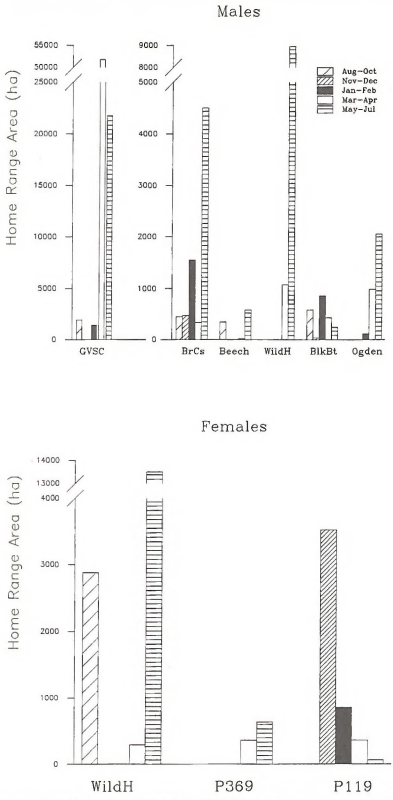


Fig. 42. 95% harmonic mean home range for breeding male (n = 6) and female (n = 3) golden eagles during 5 time periods. Territories are abbreviated as follows: BrCs = Beercase, BlkBt = Black Butte, Beech = Beecham, PL119 = PP&L 119, GVSC = Grand View Sand Cliff, Cabin = Cabin, and WildH = Wildhorse, P369 = Pole 369, Ogden = Ogden.

Home range size varied depending on the season, but 2 main trends were evident (Fig. 42). Home range size tended to be smallest during January and February, when most eagles were repairing nests and beginning incubation, and ranges were largest during May, June, and July, regardless of nest success. This was true for all male eagles and 2 of the 4 females (the range for the PP&L 119 female decreased through each season, although her radio malfunctioned late in the season, and we did not have sufficient locations on the Cabin female to analyze home range by season). Four of 10 eagles showed no significant seasonal changes in travel distances and 7 of the 10 showed no difference in travel distance throughout the day (Table 13; Fig. 43). The 3 eagles with significant seasonal differences showed no specific trend. Beecham had the largest travel distance during summer, Beercase had the largest travel distance in spring, and Ogden had the largest travel distances in winter and summer. Three eagles showed a significant interaction between season and time of day. The Black Butte male traveled farthest during winter and late in the day, the Grand View Sand Cliff male traveled farthest during the summer and early in the day, and the PP&L 119 female traveled farthest during fall and early in the day.

We reassessed burned and unburned categories for golden eagle territories. Previous classification was based on a hypothetical home range size, but we now have observed home range sizes and have calculated the percent area in each territory that burned from 1978-1993. Ninety-five percent harmonic mean home range size for eagles in 1993 was not significantly correlated with the percentage of the home range that had burned since 1980 (r = -0.08, n = 10, P = 0.83). Percentage of the territory that had burned was positively correlated with the percentage of the territory that was grassland (r = 0.68, P = 0.03, n = 10) or highly disturbed (r = 0.64, P = 0.05, n = 10), but only weakly correlated with the percentage of the territory that was high density sage, medium density sage, or medium density shadscale.

Use of OTA.—Only 1 of the territorial eagles used the OTA in 1993. The Grand View Sand Cliff male ranged to the north and into the east side of the OTA (Figs. 37 - 40). In 1992, use of the OTA was also low, but a number of pairs roosted on the southern boundary of the OTA, and occasionally ranged inside the OTA boundaries.

Selected Behavioral Use Patterns.—Distances from the nest to copulation locations were much shorter than distances to locations for all behaviors (Fig. 44). This was consistent for all territorial eagles where we observed copulations (we did not observe copulations at 4 of 9 territories) and was similar to the results for 1992. Distances for all instrumented eagles to locations where undulating flights were observed were very similar to the mean distance to locations for all behaviors, unlike the results from 1992. In that year, undulating flights were observed closer to the nest than the mean distance for all behaviors. Hunting forays were conducted at highly variable distances from nests, with no consistent pattern evident. The same was true for distances from the nest to locations where kills were made.

Table 13. Influence of season (see Fig. 36 for definitions) and time of day (2 periods: sunrise-1300, 1300-sunset) on distance traveled from the aerie by breeding golden eagles. Only unique points visited within a day are analyzed.

		Season			Interaction			Time		
Nesting Area	Sex	F	df	P	F	df	P	F	df	P
Beecham	M	20.6	1,129	<0.000				0.1	1,129	0.74
Beercase	M	3.8	2,112	0.03				0.58	1,112	0.45
Black Butte	M				3.9	3, 94	0.012			
Cabin	F	0.1	1, 16	0.82				0.62	1, 16	0.44
Grand View Sand Cliff	M				20.5	2,114	<0.001			
Ogden	M	20.9	2, 70	<0.001				0.01	1, 70	0.92
Pole 369	F	0.1	1, 78	0.71				0.44	1, 78	0.51
PP&L 119	F				59.3	3, 88	<0.001			
Wildhorse	F	2.0	1, 20	0.17				0.24	1, 20	0.63
	M	1.5	1, 27	0.23				0.04	1, 27	0.84

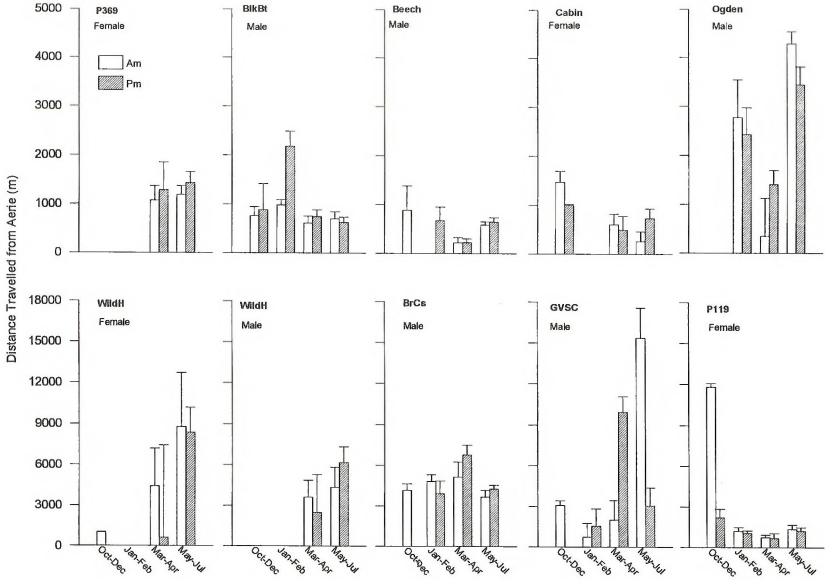


Fig. 43. Travel distances of adult golden eagles throughout the annual cycle and during AM (sunrise-1300) versus PM (1300-sunset) observations. Means + 1 SE are plotted.

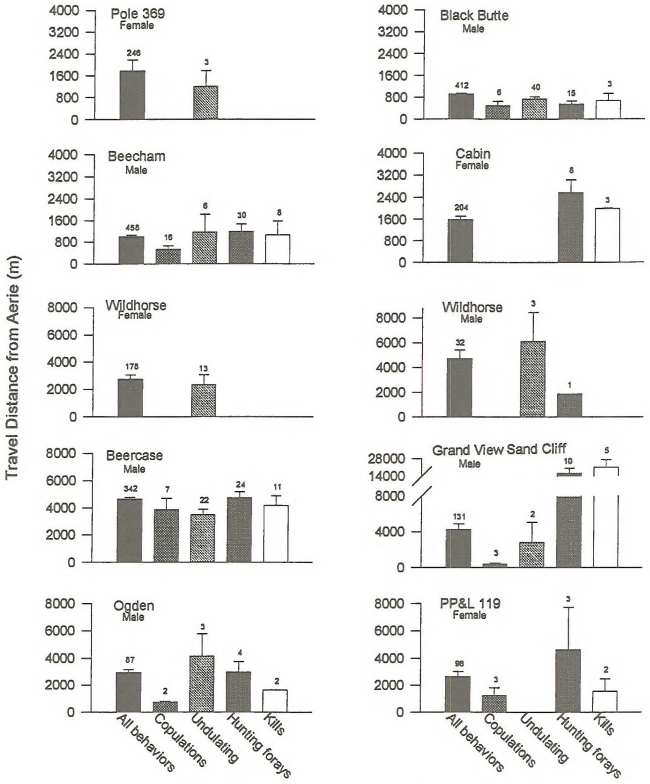


Fig. 44. Travel distances of adult golden eagles to locations where copulations, undulating flights, attacks, and kills were observed. Average travel distance to all locations is plotted first for each bird. Sample sizes are given above each mean + 1 SE.

Foraging Behavior.—We observed 38 hunting forays during 94 days of observation, and 17 of these forays were successful. This large decrease from the number of forays observed in 1992 does not appear to reflect a decrease in tracking effort. The number of forays we observed decreased by 52.5%, while the number of days and hours that territorial eagles were observed decreased by only 27.7% and 23.6%, respectively. Townsend's ground squirrels and black-tailed jackrabbits were the prey captured most often (6 squirrels = 35.5% and 5 jackrabbits = 29.4%). These were the 2 most important prey species in 1992, but jackrabbits were the primary prey by a larger margin. Other prey items captured included 1 rock dove (*Columba livia*), 1 unidentified snake, 1 yellow-bellied marmot (*Marmota flaviventris*), 1 unknown mammal, and 2 unknown prey items (Table 14). Only 2 of the 9 territorial eagles were observed successfully hunting jackrabbits, compared to 5 of 7 territorial eagles hunting jackrabbits successfully in 1992. No single prey emerged as a secondary choice (Townsend's ground squirrels were successfully hunted by 3 of 9 territories; rock doves, marmots, and snakes were each hunted successfully by 1 of 9 territorial pairs). No forays were observed at the Pole 369 territory.

We observed golden eagle hunting forays in 11 known habitat types, with sagebrush being the

Table 14. Golden eagle foraging summary. Habitat codes (Knick, this volume) were used for field classification of habitat type. Numbers in parentheses refer to the number of that prey type that was chased or taken by hunting golden eagles.

			Hunting Attempts		Hunting Success	
Territory	Sex	Habitat (code)	# Forays	Prey type chased (#)[a]	# kills	Prey type taken(#)[a]
Beecham	M	Cliff	1	Snake (1)	1	Snake (1)
		Riparian	2	Unknown (2)	0	
		Talus	2	Marmot (1)	2	Marmot (1)
				Unknown mammal (1)		Unknown mammal (1)
Beercase	M	Horsebrush	1	BTJack (1)	1	BTJack (1)
		Sagebrush(IA1)	1	Unknown (1)	0	
		Sagebrush(IB1)	1	Unknown (1)	1	Unknown (1)
		Shadscale(IB2)	2	Unknown (1) BTJack (1)	1	BTJack (1)
		Talus	2	Unknown (1) BTJack (1)	1	BTJack (1)
		Winterfat (IA3)	1	Unknown (1)	0	
		Unknown	1	BTJack (1)	1	BTJack (1)
Black Butte	M	Cliff	3	Rock Dove (3)	1	Rock Dove (1)
		Talus	1	Unknown (1)	0	
		Unknown	1	Unknown (1)	0	
Cabin	F	Riparian	2	Unknown(1) Waterfowl (1)	0	
Grand View Sand Cliff	M	Cheatgrass/Native (IIB1)	1	Unknown(1)	0	
		Cheatgrass (IIB2)	3	Unknown (2) TGS (1)	1	TGS (1)
		Cliff	1	Rock Dove (1)	0	
		Sagebrush (IA2)	3	Unknown(1)	3	Unknown (1)
				BTJack (1) TGS (1)		BTJack (1) TGS (1)
		Sagebrush (IB2)	1	Unknown(1)	0	
		Talus	1	Rock Dove (1)	0	
Ogden	M	Sagebrush(IA1)	2	Unknown (2)	0	
		Sagebrush(IB1)	2	TGS (2)	2	TGS (2)
Pole 369	F	No hunting attempts seen				
PP&L 119	F	Agriculture	1	TGS(1)	1	TGS (1)
		Cheatgrass/Native(IIB1)	1	TGS (1)	1	TGS (1)
Wildhorse	M	Sagebrush(IA1)	1	BTJack (1)	0	

[a] Prey types abbreviated as followed: TGS=Townsend's ground squirrel, BTJack=black-tailed jackrabbit , Marmot=yellow-bellied marmot

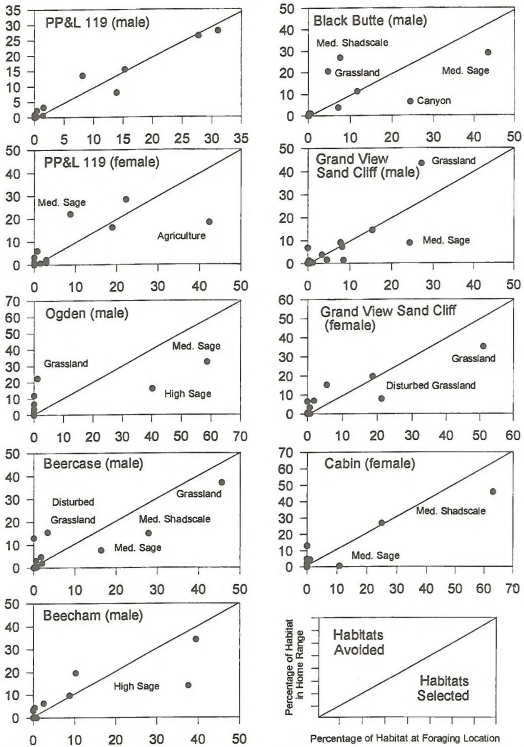


Fig. 45. Habitat used for foraging in relation to habitat availabille in golden eagle home ranges, 1993. Points within plots for each eagle represent different habitat types. Percentage of each habitat was averaged for all foraging locations and plotted on the X axis. Percentage of each habitat in the entire 1993 home range is plotted on the Y axis. The diagonal line indicates use of foraging habitat in direct proportion to availability. Points above this line indicate habitats that are avoided. Points below this line indicate habitats that selected. Points indicating extreme avoidance or selection are labelled.

most extensively used type (11 forays = 29%, and 4 of 9 pairs hunted in sagebrush habitat of either moderate or low disturbance; Fig. 45). Talus slopes and cliff faces were the next most often used habitat types, with low use of the remaining 8 types (Fig. 45). This pattern of habitat use was very similar to that observed in 1992, except that moderately disturbed shadscale was used much more extensively in 1992. Most successful forays (58.8%) occurred in moderately disturbed shrub habitats, low density or low cover type shrub habitats (horsebrush [*Tetradymia glabrata*] and shadscale) and on talus slopes. This mirrors the 1992 results, although talus slopes were not observed to be used in 1992. Forays at cliff, cheatgrass and riparian habitats had the lowest success relative to the amount of use each received. The same was true in 1992 for cliff habitats, but forays in cheatgrass (*Bromus tectorum*) and riparian areas produced a higher number of captures relative to use in 1992.

Shrublands with low to moderate disturbance were selected as foraging sites more frequently than expected based on their abundance within eagle home ranges (Fig. 46). In contrast, grasslands and disturbed areas were usually avoided. Individual eagles showed only slight variations in this respect. The Black Butte male selected canyon habitats in addition to medium density sage habitat, an assessment supported by repeated observations of this male hunting rock doves along the canyon walls. The PP&L 119 male showed no selectivity, and the female selected agricultural areas. The Grand View Sand Cliff female preferred grasslands, many of which are pastures in her territory.

Spatial Use Patterns of OTA Wintering Birds.—From 14 January to 24 March 1993 we attempted to locate the non-canyon nesting golden eagles wintering in the OTA. During 53 observation periods ($\bar{x}$ per individual = 10.6 days, n = 5, SD = 6.2 days), we successfully located an instrumented individual on 46 days; we were able to obtain a signal from the conventional tail-mounted transmitter but did not see the individual on an additional 3 days; and we did not contact an individual on the remaining 4 days. Adults tended to be found in the OTA a higher percentage of the time than did subadults (Table 15). We obtained visual or audible contact with adults an average of 98.1% (n = 3 eagles, SD = 9%) of the days that we attempted to find them. We made visual or audible contact with subadult eagles during only 41.5% (n = 2 eagles, SD = 58.79%) of our attempts, primarily because they made frequent excursions out of the SRBOPA. We obtained an average of 34.2 (n = 5, SD = 26.8) unique (not repeated within a day) locations per bird during these observations. The satellite provided an average of 126 (n = 5, SD = 14.8) unique locations per bird during this time.

The size of use areas defined by satellite fixes for each individual depended upon the quality of the location estimates included; the area decreased as less precise fixes were excluded (Table 15). Use areas defined by direct observation were smaller than those defined by satellite locations in all cases except for individual AD 5735 (Table 15). Overall, use areas defined by direct observation were smaller than those defined by satellite locations (all satellite locations: $\bar{x}$ difference = -12,197,296.6, n = 5, SD = 7,965,898.4; LQ 1 - LQ 3:

Table 15. Departure dates and use areas of wintering golden eagles in the OTA determined from satellite locations of precision LQ 0-3, LQ 1-3, and LQ 2-3 and observed locations obtained between 14 Jan and 24 Mar 1993. IDs are abbreviated as follows by an age-sex code followed by the frequency of the satellite transmitter. Age is abbreviated as: AD = adult, SAD = subadult. Males are designated by ♂ : Females are designated by ♀.

	Use area (ha) determined from					
	Satellite locations				% time	
ID	LQ 0,1,2,3 (n)	LQ 1,2,3 (n)	LQ 2,3 (n)	Observed locations (n)	located in OTA	Departure Date
AD♂ 5733	2.97E6 (124)	6.52E4 (34)	9906 (5)	9591 (27)	100.0	13 APR
SAD♂ 5734	6.43E6 (110)	1.45E6 (39)	6.50E5 (5)	28,972 (9)	0	-
AD♀ 5735	1.34E7 (150)	1.14E7 (50)	529 (6)	7596 (72)	94.4	28 MAR
AD♂ 5736	1.48E7 (120)	6.11E5 (48)	8432 (12)	3374 (51)	100.0	20 MAR
SAD♀ 5737	2.34E7 (126)	3.07E8 (39)	30,127 (6)	25,316 (12)	83.0	-

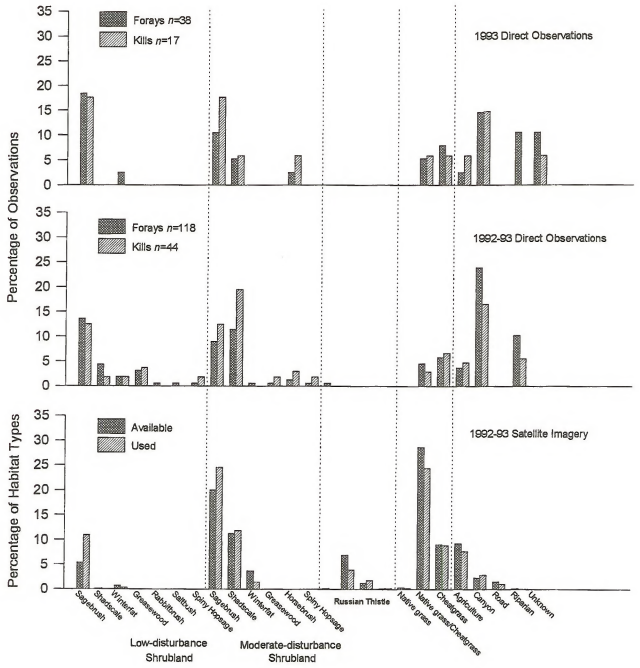


Fig. 46. Habitat types where breeding golden eagles were observed hunting (Forays) and capturing (Kills) prey in 1993 and for 1992-93 combined, and habitat available and used derived from satellite imagery within the territorial areas north of the river. Low and moderate disturbance shrubland and other habitat types are as defined by Knick (this volume).

$\bar{x}$ difference = -64,052,173.8, n = 31, SD = 135,759,077.0; LQ 2 - LQ 3: $\bar{x}$ difference = -124,981.2, n = 5, SD = 277,767.4), but small sample sizes preclude any assessment of significance.

Ranges defined by satellite locations LQ 1 - LQ 3 completely covered nearly all of the area defined by direct observation ($\bar{x}$ overlap = 99.9%, n = 5, SD = 0.18%), but the range defined by the direct observations occupied only 4% (n = 5, SD = 2.29) of the area defined by the satellite. Although using only the most precise satellite fixes (LQ 2, LQ 3) made the derived range more similar in size to the ranges derived from direct observation, the average percent of the observed range included in ranges derived from satellite locations decreased to 54.27% (n = 3, SD = 47.7) for adults and to 16.45% (n = 2, SD = 2.62) for subadults. However, using these more precise locations increased the average percentage of the range derived from satellite locations covered by the range defined by direct observations to 67.27% (n = 3, SD = 25.1) for adults and decreased the overlap for subadults to 9.4% (n = 2, SD = 11.2). The small sample of LQ 2 and LQ 3 locations may explain why such large areas of known occupancy were missed by the most precise satellite locations.

Use areas described by direct observations of adult (n = 3) golden eagles that wintered in the OTA were smaller than use areas of subadult (n = 2) eagles ($F_{(1,3)}$ = 55.23, P = 0.005, Table 15). Use areas derived from satellite locations did not describe a similar difference in size of use areas between adults and subadults (LQ 0-3: $F_{(1,3)}$ = 0.33, P = 0.6; LQ 1-3: $F_{(1,3)}$ = 1.74, P = 0.28; LQ 2-3: $F_{(1,3)}$ = 2.09, P = 0.24). There was no difference in the size of areas used by males versus size of areas used by females (observed: $F_{(1,3)}$ = 0.04, P = 0.85; LQ 0-3: $F_{(1,3)}$ = 3.09, P = 0.18; LQ 1-3: $F_{(1,3)}$ = 2.07, P = 0.25; LQ 2-3: $F_{(1,3)}$ = 0.565, P = 0.51).

The average adult departure date was 29 March (n = 3 adult eagles, SD = 12 days). AD♂ 5736 departed earliest (20 March) and traveled to central Alaska, arriving in early April. AD♂ 5733 and AD♀ 5735 departed 16 days apart (13 April and 28 March), but both traveled to southeastern Alaska/northwestern British Columbia, arriving in mid to late April. Because the non-resident subadults that we captured in the OTA showed little affiliation with any particular area within the OTA, we could not assign a departure date. SAD♂ 5734 wandered to the south soon after capture and spent the breeding season in northwestern Nevada. Although SAD♀ 5737 also wandered from the OTA during the winter, she remained in the vicinity of southwestern Idaho throughout the winter and breeding season.

DISCUSSION

Differences in Weather, Prey Abundance, and Military Activity Among Years

The 3 years of study have varied greatly in weather, prey abundance, and the timing of military activity (Fig. 27; Knick, this volume, Van Horne, this volume). The breeding season of 1991 was characterized by a cold spring and hot summer, intermediate to high numbers of prey, and a consistent, but moderate, level of military activity. Variation in temperature was less in 1992, rainfall was virtually absent, prey was extremely abundant, and military activity was concentrated as a large maneuver during June. The 5-year drought began to break in 1993, temperatures were cool and consistent throughout the breeding season, prey populations were extremely low, and military use was concentrated in large maneuvers in May and August. We believe that such annual variation has been very important in determining the year-to-year variation in behavior and productivity of raptors in the SRBOPA discussed below.

Responses of Prairie Falcons and Golden Eagles to Environmental Variation

The decline in prey abundance in 1993 appears to have influenced many aspects of prairie falcon breeding ecology. During 1993, relative to previous years, falcons utilized prey items that were more evenly distributed among prey types, ranged over larger areas, spent less time in their territories, delivered fewer prey items to their old nestlings, and dispersed from the study area sooner (Figs. 18, 19, 22 - 25). These behavioral changes are all consistent with the interpretation that falcons had a difficult time obtaining their principal prey, Townsend's ground squirrels, in 1993. Moreover, this difficulty resulted in dramatically lower falcon productivity; many falcons failed to produce nestlings in 1993, and few of those that hatched eggs were able to fledge young (see also Lehman et al., this volume). These findings are consistent with observations in the study area during a prey crash in the 1970's (U.S. Dep. Inter. 1979).

Golden eagle breeding ecology also changed in response to crashing jackrabbit populations. Relative to 1992, golden eagles preyed upon a greater variety of food items, and made fewer hunting attempts, consistent with observations in the 1970's (Steenhof and Kochert 1988). However, they did not consistently alter their ranging habits (Figs. 37 - 40). Some pairs (Black Butte, Beercase, Cabin, and Beecham) restricted their activities more closely to the canyon and riparian zone within it. These eagles roosted or perched less frequently on the Idaho Power "Big Baha" power line and reduced their foraging on the bench above the river. The pair at PP&L 119 showed a similar reduction in the use of benchlands far from their nest for foraging. PP&L 119 eagles did not concentrate on the inter-canyon areas, but hunted ground squirrels on the bench very close to their nest. As a result, these pairs had similar-sized or smaller home ranges in 1993 than in 1992. In contrast, other pairs (Grand View Sand Cliff, Wildhorse) expanded their home ranges. Apparently, eagles with access to sage stands, talus slopes, and cliff faces were able to exploit prey in those areas (rock doves, marmots, and reptiles) and did not need to wander from their home range even when jackrabbits were rare. In contrast, eagles without access to alternative, productive hunting grounds in their home range may need to range widely when jackrabbit populations decline. A paucity in the prey associated with medium to high density sage and shadscale within territories may have necessitated such ranging. Regardless of whether eagles could sustain themselves in their previous home range or had to expand into new areas, breeding success of instrumented pairs declined in 1993 relative to 1992 (3 of 7 succeeded in 1992; 1 of 7 in 1993).

Golden eagles were less consistent in their adjustment of ranging behavior to declining prey than were prairie falcons. Prairie falcons increased their travel distances as prey became rare, probably for 2 reasons: (1) they do not defend hunting areas and are therefore free to forage anywhere on the benchlands; and (2) patches of ground squirrels may be relatively evenly distributed throughout the study area so that increasing travel from the canyon directly increases the number of potential prey encountered. Golden eagles, on the other hand, are territorial and cannot expand their range without being challenged by their neighbors. Range expansion also reduces their ability to defend their territory. More importantly, defense of an all-purpose territory has the benefit of allowing eagles to become knowledgeable about the location of alternative prey in their territory and effectively exploit them.

How are Effects of Military Training Influenced by Environmental Variability?

Some of the short-term effects of military training identified in previous years were strengthened with the addition of the 1993 data. The most notable was the negative effect of live-fire training on the abundance and behavior of raptors using the firing ranges (Fig. 32). However, our observations in 1993 were more valuable in enabling us to document variations in the effects of training that appear to depend on variations in the biotic environment.

In previous years, prairie falcons nesting in the OTA shadow behaved differently from those nesting west of the OTA (Marzluff et al. 1992). Most importantly, relative to falcons west of the shadow, those nesting in the shadow exhibited reduced caching, reduced parental attendance in the territory, and increased evenness of diet. These differences prompted us to suggest that falcons nesting in the OTA shadow were "living on the edge" and had to range over large areas to raise young as successfully as falcons nesting west of the shadow. In 1993, the increased demands to range even farther in search of many small prey items apparently pushed falcons in the OTA shadow over this "edge". The differences noted above were accentuated, and breeding productivity in the shadow was extremely low (only 1 of 15 radio-tagged pairs fledged young).

Many (10 of 15) falcons west of the OTA shadow were also unsuccessful, suggesting that home ranges observed in 1993 may represent the maximum area that can be covered by breeding birds. Foraging ranges were significantly larger in 1993 than in previous years, and those were among the largest ever recorded for this species (Marzluff et al. 1992).

Falcons continued to show significant shifts in their ranging habits in response to military training (Fig. 34). Males nesting in the OTA shadow ranged farther from their aeries when provisioning offspring than males nesting west of the shadow. The observation that males nesting in the OTA shadow in 1993 did not avoid the entire

area inside Range Road during firing days, but instead sought areas within this impact area that were not being used for firing on a particular day, may explain some of this increase. Activities peripheral to Range Road may also be important, but more observations on maneuver and bivouac areas are needed.

The importance of low prey populations to prairie falcon ranging and nesting behavior in 1993 suggests that the occurrence of military training has not been the sole reason that falcons nesting in the OTA shadow behaved differently from those nesting west of the shadow. Instead, ranging habits (and likely parental attendance patterns) were dictated more strongly by prey availability. Therefore, historical differences between the OTA and the western area that influence prey abundance—some of which are natural (soil depths, rainfall patterns, and hence vegetation communities) and others which are anthropogenic (grazing, military training, fire frequencies)—were probably more responsible for the differences between falcons nesting in the OTA shadow and those nesting west of the shadow than were the immediate, short-term disturbances associated with live-fire training.

Low productivity by falcons in the OTA shadow was probably the ultimate response to the increased travel requirements brought on by low prey availability and the immediate avoidance of firing activities in their foraging range. Falcons used the OTA and area inside Range Road more in 1993 than previously reported (Table 4). Therefore, the need to avoid some areas because of firing activities may have impacted their nesting productivity more in 1993 than previously. Prey populations near nests in the OTA shadow are probably always lower than around nests west of the shadow (U.S. Dep. Inter. 1979) and as a result, falcons in the shadow typically range farther than those to the west (Fig. 19). However, in 1993, falcons nesting in the shadow apparently could not range far enough to gather enough prey to support the demands of a brood of nestlings. Falcons west of the shadow could occasionally do so, and their greater use of Townsend's ground squirrels, even when squirrels were very rare, strengthened our suspicion that habitat west of the OTA shadow is more productive for falcons than habitat in the shadow.

The composition of the raptor community using the firing ranges has changed dramatically from 1991 to 1993 (Fig. 47). Species known to nest on the bench (northern harriers, ferruginous hawks, burrowing owls, and short-eared owls) comprised over half of the community in 1991, but declined to only about 25% in 1993. Reduction in use of the ranges by owls and harriers was responsible for this decline; owls were virtually nonexistent on the ranges in 1993. In contrast, prairie falcons have steadily increased their use of the firing ranges.

Bench and canyon nesters differed in their behavioral responses to firing on the ranges (Figs. 33 - 36). Aversions to live fire were greatest in 1992. However, across the years, canyon nesters have responded more strongly to firing than bench nesters. Canyon nesters, notably prairie falcons, changed their behavioral repertoires on firing relative to non-firing days; they typically flew higher over ranges that were firing than over those not firing. However, bench nesters (ferruginous hawks and northern harriers) did not change behaviors in response to firing, but exhibited differences in behavior depending on whether they were in the firing fan or not. This suggests that nest placement with respect to the firing fan is critical to the expression of behavior by bench nesters. For example, when nests are inside the fan, behaviors such as perching are common there, but when nests are out of the fan these behaviors are rare inside of it. The behavioral repertoires of bench nesters are less flexible than canyon nesters with respect to firing because bench nesters must use their territories on firing as well as non-firing days whereas canyon nesters can change their flight styles or perch locations to avoid fans when firing occurs. Such inflexibility may make bench nesters more vulnerable to firing activities and may explain why some have been observed to abandon nesting areas in response to military training in other parts of the country (Andersen et al. 1990).

We expanded our observations of raptors in the OTA to include documentation of abundance and behavior on tracked vehicle maneuver areas and construction areas. Small samples of each type of disturbance were observed, but construction significantly reduced raptor use of the surrounding area, and vehicle maneuvers did not.

Effects of Radio Transmitters

Capturing and instrumenting individuals had a greater effect on the productivity of golden eagles

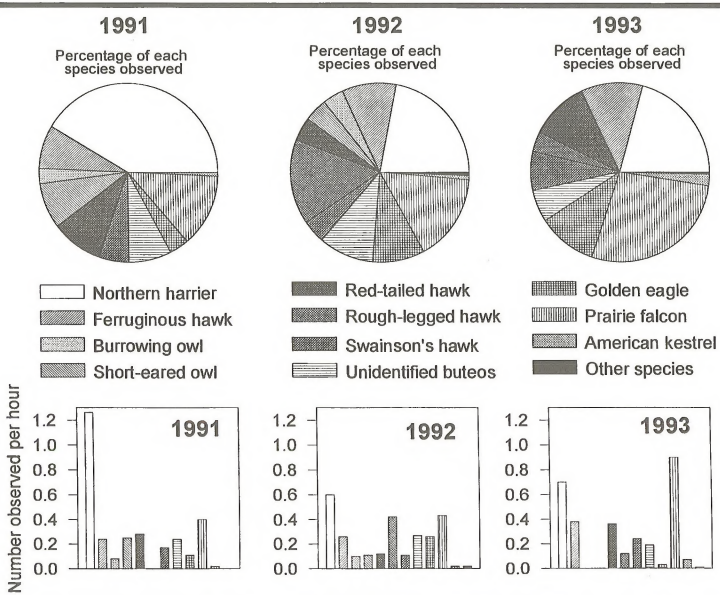


Fig. 47. Species composition of raptors observed during observations at military firing ranges in 1991, 1992, and 1993. Percentages are plotted as pieces of a pie totalling 100% of all raptors observed in the given year. Actual numbers of each species observed per hour are represented by bars of corresponding color.

than prairie falcons, and this effect on both species was greatest in 1993 (Tables 2 and 3). The significant reduction in productivity exhibited by radio-tagged eagles relative to non-instrumented controls, and the lack of a significant reduction for falcons may be related to differences in their hunting styles. Eagles are designed for maximum maneuverability and often adjust their flight path to capture their prey or follow their prey, striking at it repeatedly for many meters, before a kill is made (Collopy 1983). This type of pursuit is energetically expensive and its effectiveness may be compromised by the extra weight of a radio transmitter because the many starts and stops require that the momentum of the transmitter be overcome. Hunting success and delivery of prey items to nests will need to be compared between instrumented and control eagles to test this hypothesis. In contrast, falcons rely primarily on speed and surprise to capture ground squirrels; long chases with repeated strikes are rare (Phipps 1979). Therefore, the extra weight of a transmitter should rarely impact a falcon's maneuverability during a capture attempt, and the extra mass may increase their killing power during a stoop. Low populations of black-tailed jackrabbits and Townsend's ground squirrels in 1993 are likely the reasons that radio transmitters had their greatest effect on eagles and falcons in 1993.

Ranging Habits of Prairie Falcons

Despite the adjustments prairie falcons made to declining prey populations, many generalities reported in 1991 and 1992 were observed again in 1993. Falcon activity was greatest in the western part of the study area, showed a bimodal pattern throughout the day, and peaked in mid-season (Figs. 4 - 6). Falcons that bred successfully ranged over smaller areas than those that failed. However, even unsuccessful pairs returned on a regular basis to the area around their aerie and therefore had smaller ranges than non-breeders who were nomadic and exhibited the largest foraging ranges (Figs. 9 - 17).

The incubation period continued to be 1 of the stages of the nesting cycle during which breeding falcons traveled the greatest distances from their aeries (Fig. 8). This counterintuitive result no longer appears to be a result of a small sample size. Instead, the incubation period appears to be a time when falcons explore wide areas around their breeding sites. Perhaps during this time they assess prey populations over a large area until they find the most productive spots closest to their nests. This exploration phase was most pronounced in the OTA shadow which suggests that exploration was most important in areas with poor prey populations near the nesting cliffs.

Differences in home range size between males and females were more evident in 1993 than in previous years (Fig. 19). Thus, the magnitude of the difference in foraging range size between the sexes depended upon the food supply; maximum differences occurred when prey was moderately abundant (as in 1991) or rare (1993), but differences were minimized when prey was superabundant because male travel distances were curtailed (as in 1992).

Ranging Habits of Golden Eagles

Ranging habits of golden eagles continue to be summarized with 2 words: extremely individualistic. Few consistencies were noted with respect to sex, breeding success, and/or fire history within the territory in 1992 or 1993. Much of the variation was likely a reflection of both the variation in habitat between territories (Collopy and Edwards 1989) and the reality that long-lived, territorial, permanent residents develop individual preferences.

We have just begun to assess the potential importance of habitat composition to home range size. The importance of habitat was indicated by the observation that relative home range size changed little from 1992 to 1993; large ranges remained large and small ranges remained small, despite changes in prey abundance, nest location, and in a few cases, the individual that was tracked. The largest territories appear to have little high or medium density sage habitat–vegetation previously associated with the high densities of black-tailed jackrabbits (Smith and Nydegger 1985). As a result, long-distance excursions from the core nesting area were common. We suspect that other important correlations exist between habitat and home range size. These will be assessed from a landscape perspective when mapping of the vegetation south of the river is completed.

Excursions may lead eagles to profitable hunting areas, but they may also be a method of assessing other breeding opportunities. They did not appear to be synchronized forays by the pair.

Instead, each member of the pair may have been several kilometers apart during excursions. Anecdotal observations on 1 female this year suggest that excursions may also allow breeders in poor areas to search for better breeding opportunities. The female from Grand View Sand Cliff failed last year and wandered widely throughout the fall and winter. These excursions took her through a nearby territory (Pole 369) where she eventually settled and successfully bred (with a new mate) this year. Her previous mate remained at Grand View Sand Cliff and failed again in 1993.

Habitat Use by Prairie Falcons and Golden Eagles

Direct observations of habitat utilized for hunting and assessment of habitat selection from a vegetation map derived by remote sensing (Knick et al., this volume) led to the finding that golden eagles selected medium to high density shrublands for foraging. Sage and shadscale are particularly important. Cliff and talus habitats are also important, especially in low prey years like 1993 (Fig. 46).

A few prairie falcons also selected medium density sage and avoided disturbed grasslands and agricultural areas. However, most falcons used habitats in proportion to their availability in 1993. They exhibited less selection or avoidance of particular habitats than did golden eagles (Fig. 21).

Remote sensing of habitats appears adequate to define general features of the vegetation important to foraging eagles. However, finer-scaled habitat preferences may be less likely to be discovered by this method. For example, use of horsebrush, winterfat, and greasewood (*Sarcobatus vermiculatus*) stands was observed, but not indicated by remote sensing (Fig. 45).

Assessment of habitat use by prairie falcons depended completely on remote sensing; neither falcon locations nor associated habitats were observed. Falcon locations appear to have little bias. Beacon tests and direct observations of falcons suggest that we can obtain fixes on birds throughout the study area (Fig. 1), especially if they are not perched on the ground, and we can identify a subset of fixes with associated error circles <1,500 ha that contain the actual location (with high confidence) of a bird. However, we did not know the activity of a falcon when a fix was taken so we could not associate a particular type of habitat used with foraging such as could be done with our observations of golden eagles. We must assume that falcons were foraging when we obtained fixes and therefore interpret our assessment of habitat use as an assessment of foraging site selection. Undoubtedly, some locations were obtained on falcons that were not foraging, which may have confounded this assessment of selectivity. This is likely to be an important reason why we concluded that most prairie falcons do not select specific types of habitat.

Tracking Falcons in the Eastern Study Area.—We instrumented 5 falcons from nesting areas east of the OTA shadow to determine if they used the OTA. Falcons from the east that did not breed or that bred unsuccessfully used the OTA, but those that bred successfully in the east were not observed ranging into the OTA. Training activities were therefore unlikely to influence breeding success east of the OTA shadow.

PLANS FOR NEXT YEAR

We will continue to radio tag and monitor prairie falcons and golden eagles as was done in 1993. Direct observations of foraging by falcons and eagles is critical to our ability to assess the accuracy of determining habitat preferences by remote sensing. Therefore, we will expand our observations of raptors to determine where they are making kills. We will continue to observe the response of raptors to training on a subset of firing ranges. Observations peripheral to firing ranges will be curtailed as they are better observed by Study 1. It is unclear whether such activity influences raptor ranging behavior and more data are needed.

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Appendix A. Band characteristics and physical characteristics of adult prairie falcons captured in the SRBOPA, January-May, 1993.

Date	Territory	Band No.[a]	Color Band			Sex	Mass		Wing (mm)		Toe Pad	Radio	Time Held	No.
			color[b]	leg	code		(g)	%Crop	span	chord	(mm)	Freq.	(min)	Fledged
10 JAN	UNKNOWN	816-74900	*	*	*	M	565	*	920	307	77.8	*	*	*
11 JAN	UNKNOWN	2206-22851	*	*	*	M	590	*	*	307	77.4	*	*	*
16 JAN	UNKNOWN	*816-70251	BK	L	V/E	M	490	*	978	312	*	*	*	*
30 JAN	UNKNOWN	1807-38542	*	*	*	F	995	*	*	343	90.0	*	*	*
13 FEB	UNKNOWN	2206-22852	*	*	*	M	650	*	*	302	75.5	*	*	*
16 MAR	PRIEST IV	*816-70276	BK	L	6/B	M	600	0-25	962	307	77.3	164.237	54	0
16 MAR	UNKNOWN	*1807-01285	BK	L	E/7	F	950	26-50	1126	347	91.5	164.225	64	*
16 MAR	HELL HOLE PEREGRINE	1807-38543	RD	L	C/H	F	1000	0-25	1080	334	87.8	164.155	59	0
18 MAR	UNKNOWN	2206-22864	RD	R	3/A	M	640	26-50	966	311	80.3	164.055	64	*
18 MAR	CATTLEGUARD GATE	1807-38544	RD	R	C/K	F	915	0-25	1089	345	90.4	164.045	57	4
18 MAR	CORRAL DOWNSTREAM	1807-38545	RD	R	C/M	F	1000	26-50	1086	354	91.2	164.105	36	0
19 MAR	HENDERSON DRAW	1807-38546	RD	R	C/N	F	950	0-25	1126	353	89.5	164.175	58	0
20 MAR	BLACK BUTTE I	1807-41411	RD	R	C/T	F	950	0-25	1062	344	87.0	164.267	60	0
22 MAR	WOLF DRAW	2206-22853	RD	R	3/B	M	555	0-25	950	305	78.0	164.195	60	0
22 MAR	PRIEST UPPER	2206-22865	RD	R	2/P	M	560	0-25	972	297	78.1	164.145	42	4
22 MAR	BEECHAM	*816-70256	BK	R	N/N	M	545	0-25	927	310	73.1	[d]	40	*
24 MAR	OGDEN ROCK UPSTREAM	2206-22854	RD	R	3/C	M	545	0-25	952	304	76.9	164.035	54	0
24 MAR	BALLS PT FACE	2206-22866	RD	R	2/R	M	615	26-50	934	380	78.6	164.067	58	0
24 MAR	FANG	1807-4112	RD	R	C/U	F	1010	26-50	1074	345	90.4	164.275	58	5
26 MAR	COLT DOWNSTREAM	1807-41413	RD	R	C/V	F	1110	0-25	*	*	*	[d]	17	*
28 MAR	BITCH	1807-41414	RD	R	C/W	F	1010	0-25	*	352	92.9	[d]	18	*
29 MAR	MOTHER GIANT UPSTREAM	2206-22867	RD	R	2/S	M	490	0-25	940	302	75.8	164.075	51	1
31 MAR	CONSERVANCY FLATS	2206-22855	RD	R	C/P	M	488	0-25	948	301	76.5	164.165	61	0
01 APR	ROSIE I RED-TAIL	1807-41415	RD	R	C/X	F	880	0-25	1082	348	92.2	164.025	66	0
02 APR	PRIEST RAPIDS I	1807-38547	RD	R	C/R	F	900	0-25	1078	342	90.5	164.305	39	0
02 APR	FALCON FLATS CAVE	2206-22868	RD	R	2/T	M	590	0-25	974	308	78.7	164.125	73	0
03 APR	CARLSBAD	1807-38548	RD	R	C/S	F	878	0-25	1092	358	86.3	164.207	54	0
05 APR	GUFFEY ROCK	2206-22869	RD	R	2/U	M	570	0-25	972	310	78.2	164.255	64	5
08 APR	TOM BUTTE WEST	*816-74726	BK	L	O/V	M	520	0-25	948	310	77.3	164.295	60	0
08 APR	FEVER BASIN UPSTREAM	1807-41416	RD	R	C/Y	F	960	0-25	1100	350	91.8	164.367	62	0
13 APR	SINKER CREEK MOUTH EAST	2206-22870	RD	R	2/V	M	575	51-75	934	316	80.7	164.285	96	0
13 APR	WILDHORSE BUTTE NE	2206-22856	RD	R	3/D	M	575	0-25	932	308	77.6	164.137	62	0
15 APR	JACKASS BRIDGE	*816-74762	BK	L	3/S	M	515	0-25	930	301	77.8	164.355	74	0
16 APR	JACKASS NW	2206-22871	RD	R	2/W	M	540	0-25	944	311	78.5	164.315	69	3
18 APR	SINKER BLUFF	2206-22872	RD	R	2/X	M	505	0-25	972	312	79.1	164.345	73	0
20 APR	ROSIE UPRIVER SOUTH	1807-41417	RD	R	C/Z	F	975	0-25	*	350	90.1	164.085	60	0
21 APR	PETROGLYPHS	1807-41418	RD	R	D/A	F	845	0-25	1050	342	90.0	164.215	69	0
24 APR	ROSIE DRAW	*1807-01272	BK	L	D/9	F	895	0-25	1070	350	91.0	164.325	70	0
27 APR	UNKNOWN	1807-41423	RD	R	D/E	F	920	76-100	1068	339	89.3	164.185	75	*
28 APR	CHINA PLATE SOUTH	2206-22873	RD	R	2/Y	M	550	0-25	948	315	77.5	164.015	67	4
28 APR	UNKNOWN	*816-74902	BK	L	0/3	M	545	0-25	918	310	77.9	164.097	65	*
29 APR	A-58	*816-70248	BK	R	N/B	M	595	0-25	974	301	70.0	[d]	70	*
30 APR	CHINA CABIN SOUTH	2206-22857	RD	R	3/E	M	565	76-100	944	300	73.6	164.247	72	0
01 MAY	POLE 369 NOTCH	2206-22874	RD	R	2/Z	M	565	0-25	980	310	81.3	164.337	65	0
19 MAY	BLACK BUTTE I	2206-22858	RD	R	3/G	M	545	0-25	902	307	75.9	164.267*	72	0

[a] * denotes previously banded individuals.
[b] Color: RD - Red, BK - Black
[c] Prevously radio-tagged individual.
[d] Bird not instrumented due to gravid condition.
* Black Butte female shed radio; male was trapped and the transmitter was applied.

Appendix B. Band combinations and physical characteristics of golden eagles banded in the SRBOPA from October 1992-July 1993.[a]

Date	Trap site or nesting area	Band No.	Time Held (hr:min)	Sex	Age	Mass(g)	Wing				Bill		Head			Treatment	
							%Crop	span	width	chord	depth	Culmen	length	Hallux	Footpad	B/P/T[d]	Freq
21 Oct 92	Cabin	629-18146	1:49	F	Subad	5,110	25	2,104	385	616	31.0	46.5	127.1	55.5	147.9	-	-
23 Oct 92	PP&L 119	629-18147	2:31	F	Ad	4,100	0-25	2,098	369	623	30.7	47.3	127.3	58.7	143.5	B	4.985
23 Oct 92	PP&L119	629-18148	1:29	M	Subad	-	0-25	2,030	353	575	28.0	42.2	121.5	51.5	131.3	-	-
24 Oct 92	GV Sand Cliff	629-18149	1:25	M	Ad	3,310	0-25	1,982	340	584	28.5	39.1	116.5	53.2	132.1	B	4.945
11 Nov 92	Cabin	629-18143[b]	0:67	M	Juv	4,530	50	1,996	341	583	28.8	41.0	120.1	51.0	130.8	-	-
14 Dec 92	Ogden	629-18150	2:05	M	Ad	4,170	0-25	1,950	350	586	28.2	40.8	111.3	50.2	128.7	B	4.965
16 Dec 92	Wildhorse	629-26701	1:37	M	Ad	3,920	75-99	1,992	356	600	28.6	42.1	114.8	50.9	131.5	B	4.895
17 Dec 92	Cabin	629-26702	0:46	F	Subad	4,450	0-25	2,096	363	600	31.9	46.4	125.5	53.8	148.3	-	-
18 Dec 92	Cabin	629-26703	0:50	U	Ad[c]	4,650	0-25	2,000	-	-	32.2	51.2	123.9	40.2	127.4	-	-
07 Jan 93	Little Joe Butte	629-26704	2:10	F	Ad	4,825	0-25	2,090	385	633	30.5	45.8	124.5	57.0	136.3	T	5.066
11 Jan 93	OP 8	629-26705	2:00	M	Ad	3,775	0-25	2,006	346	612	28.2	40.0	118.3	52.0	124.5	T	5.105
12 Jan 93	Cinder Pit	629-26706	1:50	M	Ad	3,810	0-25	1,822	383	586	26.6	38.3	113.9	48.2	125.4	T	5.045
18 Jan 93	Range 30	629-26707	2:13	F	Subad	5,220	0-25	2,100	344	622	29.1	42.9	117.4	55.6	137.9	T	5.086
24 Jan 93	OTA N-border	629-26708	2:56	M	Subad	3,620	0-25	1,946	330	590	28.0	42.0	112.7	47.4	130.2	T	5.126
28 May 93	Beecham	629-26709	2:30	F	nestling	3,500	0-25	-	-	-	-	-	-	-	144.0	P[e]	-
09 Jun 93	Pole 369	629-26711	2:30	F	nestling	-	-	-	-	-	-	-	-	-	144.0	-	-
09 Jun 93	Pole 369	629-26710	2:30	F	nestling	3,600	0-25	-	-	-	-	-	-	-	147.7	P[f]	-

[a]All measurements expressed in millimeters
[b]previously banded individual
[c]Adult bald eagle
[d]Treatment: B=backpack radio P=patagial tag T=tailmount radio and backpack satellite transmitter
[e]Patagial marker code: #4 yellow, right wing
[f]Patagial marker code: #6 yellow, right wing

Appendix C. Golden eagle trapping summary, October 1992 - January 1993.

Date	Trap site or nesting area	USFWS Band	Radio freq.	Sex	Age	Attempts (days/area)	Capture time	Time at set before capture	Capture characteristics		Non-target captures/ territory
									Trap position	Leg/Toe	
21 Oct 92	Cabin	629-18146	•	F	Subad	9	1038	unknown	unknown	right/1st,2nd	3 ravens
24 Nov 92	Cabin	629-18143[a]	•	M	Juv	9	0852	unknown	left	hallux	3 ravens
17 Dec 92	Cabin	629-26702	•	F	Subad	9	1400	seconds	belly	right/3rd	3 ravens
18 Dec 92	Cabin (Bald Eagle)	629-26703	•	U	Ad	9	1055	seconds	belly	right/1st	3 ravens
23 Oct 92	PP&L119	629-18147	4.985	F	Ad	2	0817	seconds	unknown	right/3rd	1 raven
23 Oct 92	PP&L119	629-18148	•	M	Subad	2	1000	unknown	unknown	right/2nd	1 raven
24 Oct 92	Grand View Sand Cliff	629-18149	4.945	M	Ad	1	0949	few-mins	unknown	both/tarsus-foot	1 raven
14 Dec 92	Ogden	629-18150	4.965	M	Ad	4	1050	seconds	belly?	left/2nd	none
16 Dec 92	Wildhorse	629-26701	4.895	M	Ad	3	1308	seconds	head	right/2nd	none
07 Jan 93	Little Joe Butte[b]	629-26704	5.066	F	Ad	•	1000	seconds	head	right/tarsus	1 raven
11 Jan 93	OP8[b]	629-26705	5.105	M	Ad	•	1100	seconds	unknown	right/hallux	1 raven
12 Jan 93	Cinder Pit[b]	629-26706	5.045	M	Ad	•	1046	unknown	unknown	right/tarsus	2 ravens
18 Jan 93	Range 30[b]	629-26707	5.086	F	Subad	•	1445	unknown	unknown	right/3rd	•
24 Jan 93	OTA N-border[b]	629-26708	5.126	M	Subad	•	0830	unknown	unknown	left/2nd	•

[a] Previously banded as a nestling at Cabin in 1992
[b] Instrumented with a satellite transmitter.

Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas, 1992-93

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ANNUAL SUMMARY

*We conducted 1,701 point counts of raptors and ravens in the Integrated Study Area (ISA) between 16 July 1992 and 15 July 1993. Mean counts were highest in the 1993 breeding season (3.16 birds/count), slightly lower in the 1992-93 winter season (2.34 birds/count), and lowest in the 1992 dry season (1.69 birds/count). We found raptors as a group to be significantly less abundant within the OTA in most diurnal periods in all 3 seasons. Although some significant differences in diurnal activity were detected for most species in at least 1 season from breeding 1991 to breeding 1993, only a few patterns could be identified consistently from season to season and year to year. Common raven (**Corvus corax**) numbers were highest in evenings in all dry and winter seasons, whereas morning counts were highest in all breeding seasons. Northern harrier (**Circus cyaneus**) counts were consistently lower in the afternoon, whereas golden eagle (**Aquila chrysaetos**) counts were always higher in the afternoon. Differences were not always significant, but the pattern was consistent in every case. Comparisons of species' means inside and outside the OTA within diurnal periods yielded few significant results and no consistent patterns. When sites near agriculture were omitted from the analyses, differences between OTA and non-OTA sites and differences between diurnal periods often lost significance.*

In the 1993 breeding season, simultaneous observations conducted at paired OTA and non-OTA sites recorded raptors outside the OTA significantly more often than inside during military training. The same trend was found in the 1992-93 combined non-breeding seasons, but it was slightly less than significant. In the absence of military training, the difference was not significant in any season. Using only the OTA/non-OTA paired data sets, within-pair comparisons of mean raptor counts usually revealed lower counts on the OTA sites, regardless of military activity; however, the difference was rarely significant. Comparing within the OTA, sites with military training had significantly lower mean raptor counts than OTA sites without military training in all seasons. An identical comparison within the non-OTA sides of the pairs revealed no significant differences in any season.

*We classified our sites as being dominated by sagebrush (**Artemisia tridentata**), by shadscale (**Atriplex confertifolia**), by grasses and exotic annuals, or by a shrub mosaic. Raptor counts were highest at sagebrush sites in winter 1992-93 and breeding 1993. We also compared the habitat composition of sites where raptors were recorded with that of all available sites, and found signifi-*

*cant association of habitat coverages at used non-OTA sites for golden eagles in winter 1992-93 and for red-tailed hawks (**Buteo jamaicensis**) in breeding 1993. On non-OTA sites with agriculture within 2 km of the center point, counts were higher than at sites with no agriculture in at least 1 diurnal period for ravens, harriers, and rough-legged hawks (**Buteo lagopus**) in dry 1992; for ravens, prairie falcons (**Falco mexicanus**), and rough-legged hawks in winter 1992-93; and for ravens and harriers in breeding 1993.*

OBJECTIVES

1. To compare raptor detection rates inside and outside the OTA during different seasons, different diurnal periods, and periods of military training and periods of no training.

2. To assess differences in habitat use by raptors and ravens during different seasons, during different diurnal periods, and during periods of military training and periods of no training.

INTRODUCTION

Study 1 is part of a long-term investigation of the effects of military training on birds of prey and their prey populations in the Snake River Birds of Prey Area (SRBOPA). Designed as an extensive survey of raptor distribution, behavior, and response to military activity, Study 1 is comprised of a series of point counts conducted during different temporal and military-related conditions.

The overall objective of this study is to provide information about the probability that a given tract of land in the SRBOPA will be used by a certain species of raptor under a given set of conditions (season, time of day, presence/absence of military activity). This information will allow managers to schedule military training for time periods and locations that will have minimal impacts on birds of prey and allow them to prioritize areas for habitat protection and/or restoration. Although the immediate goal of the study is to assess the impact of military training on raptor distribution and behavior, the data collected herein will provide a base of information on the relative abundance of raptor species in the SRBOPA for use in long-term monitoring.

Study 1 is a year-round project with 3 field seasons a year: breeding (1 March - 15 July), dry (16 July - 31 October), and winter (1 November - 28/29 February). We are now in our third full year of research and have collected data through 7 of the 10 seasons planned for this study. This report includes preliminary analysis of data collected in 1992 and 1993 (dry 1992, winter 1992-93, and breeding 1993) as well as further analyses completed on the breeding 1991, dry 1991, winter 1991-92, and breeding 1992 data sets.

METHODS

We used 189 point count sites situated throughout the Integrated Study Area (ISA) north of the canyon rim; 70 sites are located within the OTA, and 119 sites are outside the OTA. One non-OTA site was dropped this year when access problems arose due to its location on private land. Site selection and pairing methods were described in the 1991 Annual Report (Strickler and Watson 1991). Each site is comprised of a circle with a 1,000 m radius. Point counts were conducted in the same manner as in 1991 and 1992, with each count consisting of a 20-min period of looking for all raptors and ravens within 1,000 m of the center point. We alternated intensive scans of 90-degree quadrants of the horizon through 10 x 40 binoculars with brief 360-degree naked-eye scans. Every bird seen within 1,000 m was observed for 60 sec, and the following data were recorded: species (if identifiable), time at which the bird was first seen, habitat over which the bird was flying, behavior over the 60-sec focal sample, and any appropriate comments. In addition, we collected the following weather data at each count: temperature, wind speed, wind direction, and sky cover.

Raptor detections (OTA v. Non-OTA)

Time of Day. — We censused each site during each of 3 diurnal periods (morning, afternoon, and evening) during each season. The length of each diurnal period was a function of the length

of photoperiod and consequently varied throughout the year.

Because of the lack of independence resulting from multiple counts at each site, our study design must be considered a repeated measures design, with diurnal period the main repeated factor. However, because of the nonnormal nature of our data, traditional repeated measures analyses of variance are not applicable. Permutation procedures, which are distribution-free and allow for repeated measures analysis, have recently been developed and shown to be a powerful, viable replacement for many standard parametric tests (Biondini et al. 1988; Slauson 1988; Cade and Hoffman 1990; Mielke 1991; B.S. Cade, N.E.R.C., USFWS, pers. commun.).

Traditional parametric methods assume that the underlying distribution model for a population is normal (with equal variance or an equal variance-covariance matrix) and linear. In practice, these assumptions may be very difficult to meet with ecological data (Biondini et al. 1988). Additionally, methods used to calculate the pertinent parametric statistics involve least squares; as a result, the analysis space is inherently non-metric. If the space occupied by the data is not also non-metric, the congruence principle is violated. The data space of most ecological studies is usually perceived to be Euclidean, the most common metric space (Mielke 1986). Permutation procedures are free from assumptions about normal distribution, equality of variances, or linearity, and use Euclidean distances in the analysis space, thereby satisfying the congruence principle (Biondini et al. 1988). We used multi-response permutation procedures (MRPP; Slauson et al. 1991) throughout our tests of repeated measures models of raptor detection rates.

We ran separate analyses on dry 1992, winter 1992-93, and breeding 1993 samples. Sites with fewer than 3 counts in a single season were excluded from the analysis for that season. For the overall interaction between OTA (on = 1; off = 2) and diurnal period (morning = 1; afternoon = 2; evening = 3) we examined the multivariate tests in MRPP for interaction between the group effect (OTA) and the repeated measures effect (period) using linear contrast variables between the repeated measures (morning-afternoon, morning-evening, afternoon-evening). If no significant interaction was found, univariate tests were made of the main group effect by averaging the repeated measures into 1 value and comparing it to the 2 group levels (OTA = 1 and OTA =2). The main effect of time, or in our case period, was tested by a series of pairwise comparisons that combine OTA and non-OTA data within periods (Looney and Stanley 1989). A significant interaction between OTA and period indicated that the time of day of the count influenced the difference between numbers of birds detected inside the OTA and outside the OTA. Subsequent tests for the subeffects of group and trial were performed separately within levels of OTA and period. Each type of MRPP analysis involved a different number of tests to examine for OTA and diurnal differences. Because of the multiplicity of comparisons involved, Looney and Stanley (1989) and B.S. Cade (pers. commun.) recommend adjusting P-values with the Bonferroni approach. Tests for subeffects were adjusted by dividing the critical P-values by the number of univariate tests (Harris 1985). The significance level for the general interaction analysis was $P = 0.05$. The lack of a significant result in the interaction analysis resulted in an additional 3 tests / species and a Bonferrroni adjusted significance level of $P = 0.01$. A significant result in the interaction analysis demanded a further 9 tests / species and the accepted significance level was $P = 0.005$.

Our analyses in previous reports included separate tests on 3 groups of birds: raptors and ravens combined (referred to as "all birds"or "total"); raptors; and ravens. This year we expanded our analyses to include, wherever possible, separate tests for each of the 8 most abundant species: common raven, northern harrier, prairie falcon, red-tailed hawk, golden eagle, Swainson's hawk (*Buteo swainsonii*), ferruginous hawk (*Buteo regalis*), and rough-legged hawk. We also ran tests on raptors as a group, but eliminated previous years' "total" group as redundant. Because this is the first year in which we have conducted species-level analyses, we include here results from tests for individual species in the 4 seasons on which we reported in 1992: breeding 1991; dry 1991; winter 1991-92; and breeding 1992.

Military Training. — We gathered military activity data from a variety of sources. First, we recorded any training activity heard or seen during or immediately before or after a count. The time of activity and, if possible, the type and location of the activity were recorded. The limitations of such field observations are twofold: (1) actual type and location of training are difficult to

assess, especially for artillery, which may be heard but not seen; and (2) some types of training such as maneuvers and bivouacs could take place close to the count site without being heard or seen by the observer if, for example, the activity were on the opposite side of a butte or hill from the count site.

The Idaho Army National Guard (IDARNG) provided 3 additional sources of military activity data. The Range Management Input Worksheets provided general information on the daily activity of a particular military unit, including number of personnel, number and type of vehicles and aircraft, and amount and type of ammunition. These worksheets indicated that a certain number of people and equipment were present in a very general training area (usually 1 of 23 sectors into which the 53,015-ha OTA is divided) during a 24-hr period, but gave no specific time, duration, or location of actual movement or other activity. The second IDARNG document we used was the Cinder Cone log book. A record of all communications with the range control center, the Cinder Cone log was primarily useful for determining when a range had been approved for firing. The "firing" designation, however, did not indicate whether or when firing actually occurred.

A third type of military activity data became available to us this year for the first time. Using a Global Positioning System (GPS), IDARNG personnel digitally logged the locations and dates of military bivouac sites in the OTA during periods of heavy activity in spring/summer 1993. The data were entered into the BLM's Geographic Information System (GIS), where we could access them for correlation with our count data. Accurate times and UTM coordinates of all bivouac sites allowed us to determine much more precisely which of our counts took place in the presence of at least 1 type of military training. This additional information increased our "military activity present" data set by 27% over what we had gathered during counts and from log books.

Although our military information is more accurate this year, we still do not know the extent, in terms of time or distance, to which military training may have an effect. We again applied the "3 km - 3 hr" rule to training that we used in 1992 (Strickler and Watson 1992). If military activity of any sort occurred within 3 km and up to 3 hr before and while a count was being conducted at a site in the OTA, that count was considered to have taken place during a period of military training; counts conducted when no known training took place within 3 km and 3 hr were said to have been in a period of no training. This classification of military activity, which we used in our analyses as a categorical variable (presence = 1; absence = 0), is clearly a broad definition of military activity which would result in a very conservative estimation of the influence of military activity. However, it may not respond to possible real differences in the impacts of various types, times, and locations of training. Until further information is available on the distance and time over which each of the various types of military activity are felt, we must retain this generic approach.

We compared raptor activity during periods of military training and no training inside and outside the OTA using paired sites only because this data set controls for habitat differences.

Repeated measures analysis was not possible for testing the influence of military activity on raptor detection rates inside and outside the OTA because the military activity label at each OTA site was not constant across all counts. Using only the paired counts, contingency tables were formed with categorical estimates of military activity and presence or absence of birds at OTA and off-OTA sites. Each pair of counts was scored according to whether raptors were detected at the off-OTA member of the pair but not at the OTA site (presence/absence = 1) or raptors were seen at the OTA site but not at the off-OTA site (presence/absence = 2). Because this type of scoring eliminated like pairs of counts (birds present at both sites or absent at both sites) our data set was considerably reduced. To avoid questionable results owing to sparse cells in the tables, we combined the dry and winter seasons into a single "nonbreeding" group (these seasons tend to have fewer counts conducted during a "training" designation than do breeding seasons). We performed separate analyses on each group: breeding and non-breeding. We tested the null hypothesis that military training does not influence use of the OTA by raptors and ravens using the Tables module in SYSTAT (Wilkinson 1990).

We applied Wilcoxon matched pair signed ranks tests to pairs of sites and Wilcoxon 2-sample tests for within group comparisons to further test for military training effects within the OTA. To avoid problems of independence, we averaged the

counts for each site whenever multiple records for a site were present in that data set.

We also compared OTA raptor counts in the presence of various types of military training (bivouacs; wheeled or tracked vehicles; artillery, tank, or small arms firing; air traffic) using contingency table analysis. Military activity sample sizes in the winter seasons were too small to be analyzed in this categorical test.

Raptor Detections and Habitat

Habitat analysis used the point count data described above.

Habitat Classification—During the site selection and pairing process (Strickler and Watson 1991), we described each point count site with ocular estimates of the percent cover of vegetation types (i.e., *Artemisia tridentata*, *Chrysothamnus* spp., *Ceratoides lanata* (winterfat), *Atriplex confertifolia*, *Artemisia*-dominated shrub mosaic, *Atriplex*-dominated shrub mosaic, grass/exotic annual, and agriculture). In 1992 our habitat analyses used grouped classifications based on these estimates; we classified each site as "shrub," in which the percent cover of all shrub species is ≥15%, or "grass/exotic annual," for sites with ≤15% shrub cover. The "shrub" class was further broken down into 2 categories: sagebrush-associated shrub (including *Artemisia tridentata*, *Chrysothamnus* spp., *Ceratoides lanata*, or a mosaic of 2 or more species), shadscale-associated shrub (including *Atriplex confertifolia*, *Grayia spinosa*, *Artemisia spinescens*, or a mosaic of 2 or more species). The grass/exotic annual class includes perennial native grasses, non-native annual grasses such as cheatgrass (*Bromus tectorum*), nongrass exotic annuals such as Russian thistle (*Salsola iberica*), and fallow agriculture. Sites with ≥25% productive agriculture were omitted from habitat analyses.

This year we again evaluated habitat association by raptors using categorical habitat data, but our groups were derived from more precise estimates of the habitat composition of our sites available to us from the GIS for the first time. Using GIS information on the percent cover of all habitat classes (Knick et al. 1992), we reclassified our sites into the same 3 groups we used last year. We added a fourth group, shrub mosaic, for 7 shrub sites that contained ≥15% of both sagebrush-associated shrub and shadscale-associated shrub and therefore could not be assigned to any other group. Sites with ≥15% agriculture according to the GIS were omitted from categorical analyses. Because reclassification altered the original groupings, we reran habitat analyses on 1991-92 data sets in addition to 1992-93 analyses.

Time of Day.— The interaction between habitat class and the repeated effect of diurnal period was tested with a multivariate, repeated measures permutation procedure (Slauson et al. 1991). Applicable univariate tests for main effects and subeffects were run depending upon the significance of the 2-way interaction, with Bonferroni adjustments for multiple comparisons, where appropriate, applied as described above. We ran separate analyses on each season and on each common species.

Habitat Use v. Availability.— We evaluated use and availability among habitat types by comparing the habitat composition of used sites with that of available sites (used + unused). Habitat composition was defined as the percent cover at each site of the 26 habitat classes described by Knick et al. (1992) plus agriculture. Use of each site in each season by individual species and by raptors as a group was assessed. We use MRPP to calculate probabilities that used sites could be selected by chance from available sites; small P values indicated that habitat class coverages were concentrated in the group of used sites (Cade and Hoffman 1990).

Agricultural Lands.— To evaluate the effect of private agricultural lands outside the OTA on our counts, we classified all non-OTA sites as "near agriculture" ("ag") if there was irrigated and/or cultivated land (pasture or intensely managed) within 2 km of the center point of the site and "no agriculture" ("non-ag") if there was no agriculture within 2 km of the center point, as determined by the GIS vegetation map.

We compared counts at ag sites and non-ag sites during different times of day using MRPP to perform repeated measures permutation tests. To assess the influence of agricultural lands on the OTA/off-OTA comparisons, we omitted all "near agriculture" sites and ran the multivariate repeated measures permutation procedures described above, testing for the interaction of OTA and diurnal period. Different results between this test and the test in which agricultural lands were included would indicate that ag lands have a

strong effect on the distribution of raptors and ravens in the ISA.

RESULTS

Raptor Detections (OTA v. Non-OTA)

We conducted 1,701 point counts between 16 July 1992 and 15 July 1993, 630 at OTA sites and 1,071 at off-OTA sites. Sixty-seven percent (2,744) of the 4,077 birds detected at these counts were common ravens. Fifteen species of raptors were recorded (listed in order of frequency of occurrence; Appendix A): northern harrier; rough-legged hawk; prairie falcon; golden eagle; red-tailed hawk; Swainson's hawk; ferruginous hawk; American kestrel (*Falco sparverius*); turkey vulture (*Cathartes aura*); short-eared owl (*Asio flammeus*); bald eagle (*Haliaeetus leucocephalus*); burrowing owl (*Speotyto cunicularia*); sharp-shinned hawk (*Accipiter striatus*); northern goshawk (*Accipiter gentilis*); Cooper's hawk (*Accipiter cooperii*).

Seasonal Patterns.— The average of all birds per count over 3 seasons was 2.40; raptors averaged 0.78 birds per count, and the average raven count was 1.61. Average raptor counts were highest in the 1993 breeding season (1.40 birds per count), considerably lower in the 1992-93 winter season (0.60 birds per count) and lowest in the 1992 dry season (0.35 birds per count), continuing the pattern of annual cyclicity we found in 1991-92 (Fig. 1a). Ravens followed a similar pattern (Fig. 1a). Compared with 1991-92, when we saw 254 and 493 raptors in the dry and winter seasons respectively, the 1992-93 dry and winter season counts were slightly lower with 201 and 341 birds (Appendix A). 791 raptors were counted in 1993 breeding season compared to 816 raptors in breeding 1991 and only 585 raptors in breeding 1992. Raven counts have declined in every consecutive breeding season from a high of 1,475 in breeding 1991 to 1,250 in 1992 and 1,000 in 1993 (Appendix A). Ravens were also less abundant in winter 1992-93 (988 birds) than in the previous winter (1,343 birds).

The same consistent cyclical pattern was found for each of the raptor species (Figs. 1b, 1c). Northern harriers showed the most consistent level of seasonal change from year to year (Fig. 1b). Prairie falcon and rough-legged hawk numbers showed the same cyclical seasonal pattern, but peak numbers varied greatly across years (Figs. 1b, 1c). Golden eagles kept a very consistent low level presence but followed the same seasonal pattern (Fig. 1b). Red-tailed hawk numbers were more erratic than golden eagles especially in the seasons from dry 1991 to winter 1992 (Fig. 1c). Both ferruginous hawk and Swainson's hawk numbers reflected their very strong seasonal appearance, here in the breeding seasons and virtually absent in the winter seasons (Fig. 1c).

A closer look at raptors (Figs. 2a-c) and ravens (Figs. 3a-c) during the 3 breeding seasons shows some very distinct differences. The seasonal pattern for raptors in breeding 1991 (Fig. 2a) and breeding 1993 (Fig. 2c) showed a slow but consistent decline from March (early season) to July (late season). The breeding 1992 decline was much steeper and occurred earlier than in the other breeding seasons (Fig. 2b). Similar patterns of decline were present inside and outside the OTA, but numbers were generally lower in the OTA. Ravens showed very different patterns both from the raptors, from year to year and, in breeding 1992, inside and outside the OTA (Figs. 3a-c). Also, within each season, numbers of ravens were not always lower in the OTA. High numbers of ravens were maintained throughout the breeding 1991 season (Fig. 3a); numbers declined sharply in breeding 1992 from early to mid-season with the OTA ravens continuing to decline while the non-OTA numbers were maintained into the late season (Fig. 3b). Breeding 1993 showed maintenance of the early season numbers into the mid-season and then a fairly sharp decline in both the OTA and non-OTA areas as the season progressed to July (Fig. 3c).

Time of Day.— Significant interactions between OTA and diurnal period were found for raptors only in dry 1991 ($d = 2.00$, $P = 0.011$) and dry 1992 ($d = 1.97$, $P = 0.003$) (Fig. 4a), indicating that abundance of raptors through the day did not differ relative to the OTA in the breeding and winter seasons. In breeding 1991, winter 1991-92, and breeding 1992, mean counts of raptors were similar between OTA and non-OTA sites across all periods ($P > 0.30$ in all seasons) (Table 1). Raptors were more abundant in the evening than in the morning or afternoon in breeding 1991 and winter 1991-92, although this trend was slightly less than significant in the morning/evening comparison in breeding 1991 ($d = 2.96$, $P = 0.018$) and winter 1991-92 ($d = 2.09$, $P = 0.047$). In breed-

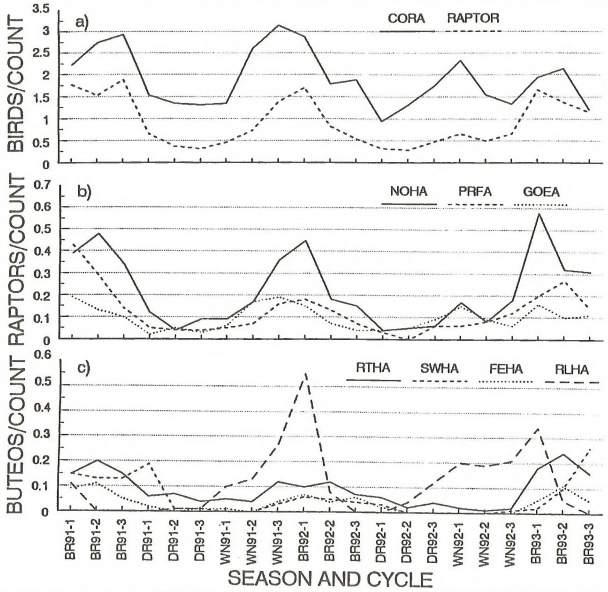

Fig. 1. Mean counts for raptors (a), common ravens (CORA)(a), northern harriers (NOHA)(b), prairie falcons (PRFA)(b), golden eagles (GOEA)(b), red-tailed hawks (RTHA)(c), Swainson's hawks (SWHA)(c), ferruginous hawks (FEHA)(c), and rough-legged hawks (RLHA)(c) from April 1991 (breeding 1991, cycle 1) through 15 July 1993 (breeding 1993, cycle 3) in the integrated study area of the Snake River Birds of Prey Area.

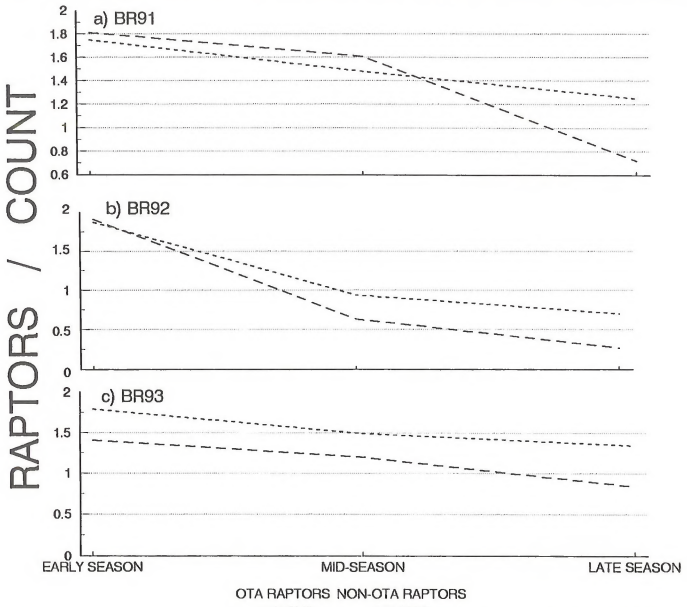

Fig. 2. Mean counts for raptors inside and outside the OTA during breeding season 1991 (a), 1992 (b), and 1993 (c).

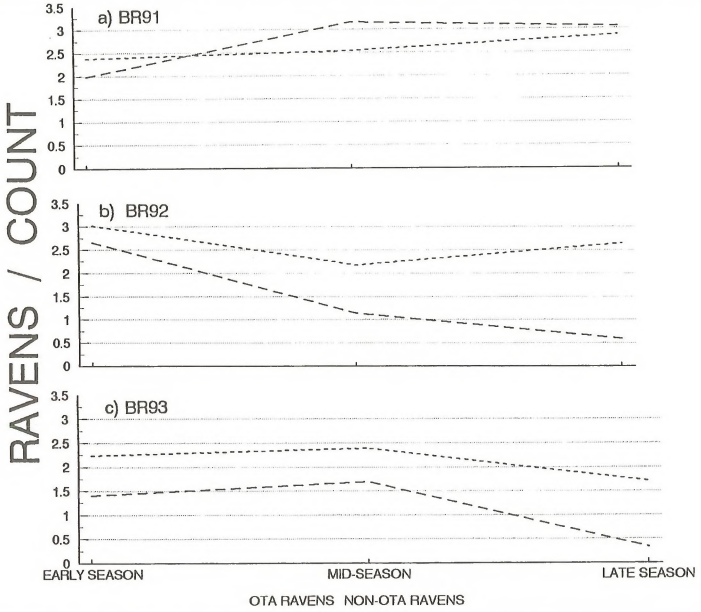

Fig. 3. Mean counts for common ravens inside and outside the OTA during breeding season 1991 (a), 1992 (b), and 1993 (c).

ing 1992, raptors were significantly more abundant in the morning than in the evening. In winter 1992-93 (Fig. 4b) and breeding 1993 (Fig. 4c), no diurnal patterns were found, but raptor numbers were significantly higher off the OTA than on regardless of time of day (winter: $d = 0.59$, $P < 0.001$; breeding: $d = 1.00$, $P = 0.010$).

Because the effects of diurnal period and OTA influence each other in the dry seasons, we evaluated counts within OTA and non-OTA subsets for differences in timing of use of OTA and non-OTA areas. No diurnal patterns were found in either dry season ($P > 0.15$ in all cases) (dry 1992, Fig. 4a). We tested the OTA effect within each time period and found OTA counts to be lower than non-OTA counts in all periods. These were significant in the morning and evening in dry 1991 (morning: $d = 0.95$, $P = 0.002$; evening: $d = 0.50$, $P = 0.001$) and in the afternoon in dry 1992 ($d = 0.63$, $P = 0.005$) (Fig. 4a), and approaching significance in dry 1991 afternoons ($d = 0.67$, $P = 0.010$) and dry 1992 mornings ($d = 0.61$, $P = 0.010$).

When non-OTA sites near agriculture were excluded from the analysis, the significant interactions between area and period in the dry seasons were eliminated, but there remained significantly more raptors outside the OTA than inside across all periods ($d = 2.00$, $P = 0.008$) in dry 1991. All other findings were unaffected by the exclusion of agricultural lands.

Ravens.— The OTA*period effect was significant in breeding 1991 ($d = 1.94$, $P = 0.031$) and dry 1991 ($d = 1.98$, $P < 0.001$) for ravens (Table 2). We saw more ravens in the morning than in the afternoon within the OTA in both seasons (breeding: $d = 5.00$, $P = 0.001$; dry: $d = 4.52$, $P = 0.005$). OTA counts were lower than non-OTA counts within all periods in dry 1991 (morning: $d = 2.20$, $P = 0.002$; afternoon: $d = 1.75$, $P < 0.001$; evening: $d = 3.30$, $P = 0.004$).

In all other seasons, time of day did not influence raven use of the OTA and non-OTA ISA ($P > 0.05$ in all seasons), and ravens were more abundant off the OTA than on regardless of diurnal period [winter 1991-92: $d = 2.38$, $P = 0.010$; breeding 1992: $d = 2.33$, $P = 0.002$; dry 1992: $d = 1.74$, $P < 0.001$ (Fig. 4a); winter 1992-93: $d = 2.29$, $P = 0.002$ (Fig 4b); breeding 1993: $d = 1.80$, $P = 0.002$ (Fig. 4c)]. We found diurnal differences in abundance between morning and evening in winter 1991-92 ($d = 6.54$, $P = 0.033$), breeding 1992 ($d = 6.61$, $P < 0.001$), and winter 1992-93 ($d = 8.79$, $P = 0.001$) (Fig. 4b), and between afternoon and evening in both winter seasons (1991-92: $d = 7.99$, $P = 0.001$; 1992-93: $d = 7.36$, $P = 0.001$). Although not all the numbers were significant, a consistent pattern of diurnal activity for ravens over the whole ISA did emerge. For all breeding seasons, ravens were more abundant in the morning than in the evening, the only exception was in breeding 1993 when morning and evening sightings were equal. For all dry and winter seasons, more ravens were counted in the evening than in the morning or afternoon.

Raven abundance was strongly influenced by proximity to agriculture. In the 1991 breeding and dry seasons, diurnal differences were eliminated when only non-agricultural lands were considered. Use of OTA sites remained significantly lower than use of non-ag off-OTA sites in dry 1991 ($d = 0.87$, $P = 0.009$), but differences between OTA and non-OTA sites in all other seasons lost significance. The difference between morning and evening counts in winter 1991-92 also diminished ($d = 5.93$, $P = 0.084$).

Northern harriers.— Harriers exhibited different daily patterns of abundance inside and outside the OTA (Table 3) only in the 1991 dry season ($d = 2.06$, $P = 0.003$). In that season, we counted more harriers at non-OTA sites than at OTA sites for all periods, with morning numbers approaching significance ($d = 0.22$, $P = 0.01$). Harrier numbers were similar among diurnal periods inside and outside the OTA except for at non-OTA sites in the morning and afternoon, where higher numbers in the morning approached significance ($d = 1.07$, $P = 0.021$).

Harrier detections were greater in non-OTA areas than in the OTA across all periods in winter 1992-93 ($d = 0.19$, $P = 0.030$). In breeding 1991, morning counts tended to be higher than afternoon counts ($d = 1.56$, $P = 0.016$), and evening counts were higher than afternoon counts ($d = 1.46$, $P = 0.006$). In breeding 1992 morning counts were higher than both afternoon ($d = 1.723$, $P = 0.002$) and evening counts ($d = 1.65$, $P = 0.013$). In winter 1991-92 evening counts were also higher than afternoon counts ($d = 1.17$, $P = 0.004$). Dry 1992 and breeding 1993 yielded no differences in harrier abundance in any area or at any time of day ($P > 0.11$ in all cases). Although the numbers were not always significant, harriers in the ISA

Table 1. Mean counts of all raptor species at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	1.33	1.26[c]	1.81[c]	1.40	1.20	1.14	1.88	1.50	1.41	1.33	1.77	1.35	1.23	1.13	1.17
SD	1.47	1.35	2.03	1.82	1.71	1.12	2.38	1.55	1.31	1.47	1.82	1.51	1.13	1.36	1.91
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.61	0.42	0.31	0.22[d]	0.27[e]	0.22	0.16[g]	0.58	0.81[e]	0.54[g]	0.40	0.39[d]	0.45	0.45	0.26
SD	2.27	0.86	0.69	0.59	0.59	0.62	0.56	1.77	2.81	0.96	0.74	1.85	0.68	0.93	0.46
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	119	116	255	86	84	85
Mean	0.80	0.74[c]	1.04[c]	0.78	0.59	0.60	1.14	0.91	0.92	0.82	0.97	0.79	0.85	0.63	0.89
SD	1.07	1.03	1.22	1.08	0.91	0.84	1.33	1.14	1.14	1.13	1.16	1.05	1.08	0.90	1.14
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	1.17[b]	1.09	0.82[b]	0.94	1.14	1.00	0.67	1.08	1.18	1.14	0.91	0.90	0.97	0.91	0.83
SD	1.31	1.44	1.31	1.27	1.25	1.31	1.22	1.41	1.35	1.52	1.35	1.21	1.11	1.31	1.22
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.38	0.38	0.30	0.19	0.20	0.16[f]	0.21	0.45	0.49	0.51[f]	0.34	0.32	0.37	0.33	0.26
SD	0.79	0.89	0.62	0.50	0.55	0.50	0.45	0.88	0.89	1.03	0.69	0.75	0.78	0.82	0.64
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.53	0.66	0.61	0.39[d]	0.37	0.44	0.34	0.73[d]	0.63	0.79	0.76	0.58	0.48	0.65	0.62
SD	0.82	1.02	0.91	0.64	0.68	0.65	0.59	1.03	0.87	1.16	1.03	0.88	0.81	0.93	0.91
Breeding 1993															
N	189	189	189	210	70	70	70	257	119	119	119	258	86	86	86
Mean	1.36	1.40	1.42	1.15	1.03	1.11	1.31	1.54	1.55	1.57	1.49	1.30	1.27	1.38	1.26
SD	1.45	1.45	1.43	1.18	1.13	1.11	1.29	1.56	1.59	1.60	1.50	1.44	1.39	1.51	1.42

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

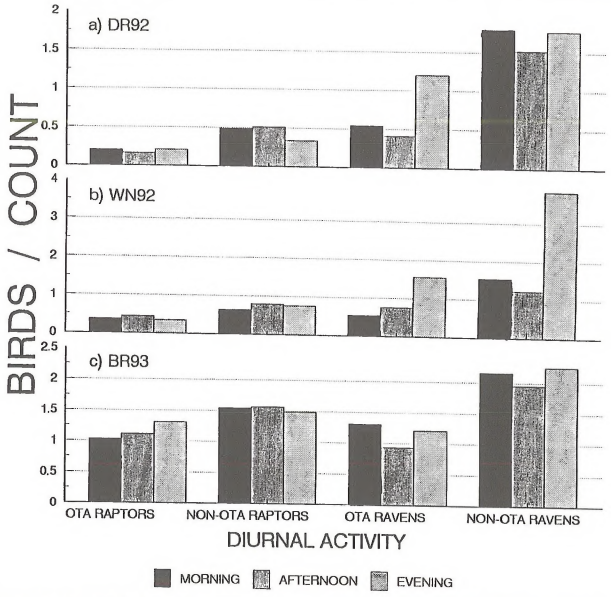

Fig. 4. Mean counts of raptors and ravens inside and outside the OTA during morning, afternoon, and evening diurnal periods in the 1992 dry season (a), 1992-93 winter season (b), and the 1993 breeding season (c).

Table 2. Mean counts of common ravens at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	3.06	2.47	2.38	2.71	3.33[a]	1.91[h]	2.89	2.60	2.90	2.78	2.09	2.20	2.78	1.99	1.81
SD	4.47	3.90	4.10	4.42	4.55	2.91	5.43	4.02	4.44	4.35	3.09	3.41	4.25	3.12	2.60
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	1.35	1.02	1.82	0.45[d]	0.83[a,h]	0.12[i,h]	0.39[g]	1.95	1.66[e]	1.55[i]	2.64[g]	0.39[d]	0.90	0.51	0.74
SD	3.34	3.27	7.71	2.30	3.69	0.40	1.33	6.24	3.09	4.00	9.54	0.72	1.90	1.30	2.23
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	86	85
Mean	1.88	1.56[c]	3.68[c]	1.69[d]	1.43	1.01	2.61	2.79[d]	2.15	1.90	4.31	2.16	1.51	1.24	3.72
SD	2.66	3.50	9.30	4.62	2.20	1.40	7.51	6.67	2.87	4.27	10.18	6.55	1.90	2.14	10.85
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	2.82[b]	1.88	1.88[b]	1.47[d]	2.34	1.36	0.70	2.62[d]	3.09	2.19	2.57	2.06	2.38	2.00	1.79
SD	5.03	3.08	5.36	2.29	3.02	1.99	1.20	5.50	5.90	3.54	6.59	3.73	4.29	3.44	3.40
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	1.33	1.11	1.56	0.72[d]	0.54	0.41	1.20	1.69[g]	1.79	1.52	1.77	0.81	0.91	0.71	0.83
SD	2.45	2.55	3.44	1.87	1.14	0.94	2.84	3.24	2.87	3.07	3.74	1.64	1.66	1.34	1.88
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	1.17[a]	1.06[a]	2.99[a,c]	0.96[d]	0.54	0.76	1.57	2.20[g]	1.55	1.24	3.82	1.63	0.86	0.95	3.07
SD	3.69	2.11	8.83	2.82	1.11	1.26	4.55	6.42	4.53	2.46	9.69	5.60	1.33	1.38	9.38
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	1.85	1.58	1.87	1.15[d]	1.31	0.93	1.21	1.54[g]	2.16	1.96	2.25	1.69	1.48	1.36	2.24
SD	3.24	2.67	5.43	1.74	1.89	1.28	1.98	1.56	3.79	3.16	6.65	4.69	1.77	2.20	7.63

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

Table 3. Mean counts of Northern harriers at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	0.25	0.25[a]	0.47[c]	0.38	0.57	0.14	0.42	0.42	0.45	0.31	0.50	0.34	0.36	0.26	0.42
SD	0.56	0.51	0.85	0.93	1.22	0.39	0.92	0.70	0.70	0.56	0.81	0.63	0.57	0.51	0.77
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.12	0.06	0.07	0.03	0.04[e]	0.01	0.03	0.11	0.17[e]	0.08	0.09	0.09	0.16[e]	0.05	0.06
SD	0.34	0.30	0.27	0.17	0.20	0.12	0.17	0.36	0.40	0.36	0.32	0.30	0.40	0.21	0.24
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	84	85
Mean	0.21	0.14[c]	0.27[c]	0.20	0.19	0.14	0.29	0.21	0.22	0.14	0.26	0.17	0.20	0.10	0.22
SD	0.58	0.42	0.55	0.53	0.60	0.43	0.54	0.52	0.57	0.41	0.56	0.50	0.57	0.30	0.56
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	0.39[a]	0.18[a]	0.21	0.22	0.43	0.09	0.16	0.28	0.38	0.23	0.23	0.21	0.28	0.16	0.19
SD	0.78	0.52	0.56	0.61	0.81	0.37	0.53	0.54	0.77	0.59	0.58	0.50	0.55	0.43	0.52
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.06	0.03	0.06	0.04	0.04	0.01	0.07	0.06	0.08	0.03	0.06	0.03	0.02	0.02	0.03
SD	0.27	0.16	0.24	0.23	0.27	0.12	0.26	0.23	0.27	0.18	0.24	0.16	0.15	0.15	0.18
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.12	0.10	0.15	0.07	0.06	0.03	0.13	0.15	0.15	0.13	0.17	0.13	0.12	0.12	0.15
SD	0.37	0.40	0.45	0.29	0.23	0.17	0.41	0.46	0.42	0.49	0.48	0.43	0.36	0.42	0.50
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.46	0.33	0.42	0.36	0.34	0.29	0.46	0.43	0.52	0.35	0.40	0.34	0.44	0.28	0.30
SD	0.77	0.58	0.77	0.71	0.70	0.62	0.81	0.71	0.80	0.56	0.74	0.64	0.78	0.48	0.63

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

exhibited a very consistent trend, over all seasons and years, that of afternoon counts being lower than morning or evening counts. Results were effectively unchanged by the exclusion of non-OTA sites near agriculture from the analysis.

Prairie falcons.— The OTA*period interaction was significant for prairie falcons (Table 4) in the 1992 dry season (d = 2.10, P = 0.049). Within subsets of diurnal period and OTA/non-OTA area, however, only the difference between the OTA and non-OTA ISA in the morning approached significance (d = 0.070, P = 0.024).

In winter 1992-93, we detected more prairie falcons outside the OTA than inside regardless of time period (d = 0.13, P = 0.047). We found no significant differences in any breeding season. Diurnal differences were very limited and only slightly less than significant after applying the Bonferroni adjustment. There were higher counts in the morning than in the evening in dry 1991 (d = 0.89, P = 0.029), and higher morning counts compared to afternoon counts in winter 1991-92 (d = 1.13, P = 0.026). The exclusion of non-OTA ag sites from the analyses eliminated the significant interaction and all detection differences for prairie falcons.

Red-tailed hawks.— Red-tailed hawks exhibited differences in diurnal activity inside and outside the OTA more often than any other raptor species (Table 5). Patterns of daily occurrence differed significantly between the OTA and off-OTA in breeding 1991 (d = 2.05, P = 0.049), dry 1991 (d = 2.08, P = 0.011), breeding 1992 (d = 2.07, P = 0.020), and winter 1992-93 (d = 2.13, P = 0.020). We saw more red-tailed hawks off the OTA than on in the morning in breeding 1991 (d = 0.29, P = 0.026), dry 1991 (d = 0.11, P = 0.019), and breeding 1992 (d = 0.10, P = 0.011), and in the afternoon in breeding 1991 (d = 0.27, P = 0.008) and winter 1992-93 (d = 0.05, P = 0.050). These differences were less than significant with the Bonferroni adjusted significance levels. Within the OTA and non-OTA subsets, we found no strong differences among diurnal periods.

Winter 1991-92, dry 1992, and breeding 1993 had no significant OTA*period interactions. Red-tailed hawk counts, while always higher off the OTA across all periods, were not significantly different (P > 0.10 in all seasons). We did detect significantly higher numbers in the afternoon than in the evening in dry 1992 (d = 1.00, P = 0.009) and breeding 1993 (d = 1.35, P = 0.007). This trend was reversed in winter 1991-92 (d = 1.04, P = 0.051) but was not significant. In breeding 1993, afternoon counts were also higher than morning counts (d = 1.03, P < 0.001).

The diurnal period * OTA interactions and diurnal differences were erased when sites near agriculture were excluded from the breeding 1991, dry 1991, and breeding 1992 analyses. We tended to observe higher numbers of red-tailed hawks outside the OTA vs. inside in both breeding seasons (1991: d = 0.22, P = 0.027; 1992: d = 0.14, P = 0.019). Winter 1992-93 results were unchanged. Differences between afternoon and evening counts in winter 1991-92 (d = 1.08, P = 0.078) and dry 1992 (d = 0.67, P = 0.39) were no longer significant.

Golden eagles. — Golden eagles (Table 6) showed no variation in relative use of the OTA through the day in any season, nor any overall difference in abundance between the OTA and off-OTA (P > 0.07 in all cases). Golden eagles were generally more abundant in the afternoon than in either morning or evening periods. These differences were significant or close to significant in breeding 1991 (morning/afternoon: d = 1.17, P = 0.037; morning/evening: d = 1.04. P = 0.007), dry 1991 (afternoon/evening: d = 1.11, P = 0.020), winter 1991-92 (morning/afternoon: d = 1.17, P = 0.037; morning/evening: d = 1.12, P = 0.010) and in breeding 1992 (evening/morning: d = 1.03, P = 0.014; evening/afternoon: d = 0.46, P < 0.001). Counts were similar across all periods in dry 1992, winter 1992-93, and breeding 1993. Excluding non-ag sites reduced the differences found in afternoon/evening comparisons in dry 1991 (d = 1.14, P = 0.13) and morning/evening comparisons in winter 1991-92 (d = 1.15, P = 0.36).

Swainson's hawks. — In breeding 1993, Swainson's hawk detections (Table 7) varied diurnally between OTA and non-OTA sites (d = 2.04, P = 0.012), with more detections off the OTA than on in the morning (d = 0.26, P = 0.03) and in the afternoon (d = 0.18, P = 0.022). No differences were found among periods or between areas in any other season (P < 0.08 in all cases); there were insufficient data for analysis in dry 1992 and winter 1992-93. Excluding sites near agriculture from the analysis did not affect our results.

Table 4. Mean counts of prairie falcons at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	0.25	0.25	0.38	0.32	0.26	0.30	0.40	0.28	0.24	0.22	0.37	0.31	0.28	0.24	0.42
SD	0.56	0.62	0.70	0.68	0.65	0.71	0.68	0.60	0.50	0.57	0.71	0.65	0.55	0.63	0.76
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.06	0.05	0.02	0.03	0.06	0.01	0.01	0.05	0.07	0.07	0.02	0.05	0.05	0.08	0.02
SD	0.26	0.26	0.12	0.17	0.23	0.12	0.12	0.25	0.28	0.31	0.13	0.25	0.21	0.35	0.15
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	84	85
Mean	0.13	0.08	0.08	0.08	0.09	0.06	0.10	0.10	0.15	0.09	0.08	0.10	0.13	0.07	0.11
SD	0.35	0.38	0.32	0.27	0.28	0.23	0.30	0.39	0.38	0.45	0.32	0.39	0.34	0.46	0.38
Breeding 1992															
N	190	190	190	70	70	70	70	360	120	120	120	258	86	86	86
Mean	0.13	0.12	0.14	0.15	0.16	0.14	0.16	0.11	0.11	0.10	0.12	0.13	0.14	0.10	0.15
SD	0.35	0.35	0.41	0.40	0.37	0.39	0.44	0.36	0.34	0.33	0.40	0.39	0.38	0.34	0.45
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.04	0.02	0.03	0.01	0	0	0.03	0.04	0.06	0.03	0.03	0.02	0.06	0	0.01
SD	0.19	0.23	0.18	0.10	0	0	0.17	0.24	0.24	0.29	0.18	0.15	0.24	0	0.11
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.07	0.11	0.08	0.05	0.01	0.07	0.07	0.11	0.10	0.13	0.09	0.08	0.05	0.08	0.10
SD	0.25	0.34	0.28	0.22	0.12	0.26	0.26	0.33	0.30	0.38	0.29	0.30	0.21	0.35	0.31
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.23	0.16	0.21	0.21	0.29	0.14	0.20	0.20	0.20	0.18	0.21	0.22	0.21	0.20	0.27
SD	0.50	0.46	0.44	0.50	0.57	0.46	0.47	0.45	0.46	0.46	0.43	0.47	0.46	0.48	0.47

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

Table 5. Mean counts of red-tailed hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	0.16	0.16	0.17	0.09[d]	0.09	0.06[f]	0.14	0.21	0.20	0.23[f]	0.19	0.19[d]	0.20	0.19	0.19
SD	0.44	0.44	0.42	0.34	0.41	0.24	0.35	0.48	0.46	0.51	0.46	0.47	0.48	0.47	0.45
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.06	0.07	0.04	0.02	0.00	0.07	0.00	0.08	0.09	0.08	0.07	0.04	0.01	0.08	0.01
SD	0.29	0.37	0.38	0.29	0.00	0.49	0.00	0.38	0.37	0.27	0.48	0.18	0.11	0.28	0.11
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	84	85
Mean	0.05	0.05	0.11	0.04	0.03	0	0.10	0.08	0.06	0.09	0.11	0.09	0.05	0.10	0.12
SD	0.24	0.06	0.33	0.20	0.17	0	0.30	0.31	0.27	0.31	0.34	0.32	0.26	0.33	0.36
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	0.05	0.15	0.09	0.04[d]	0	0.09	0.04	0.13	0.08	0.18	0.12	0.11[d]	0.07	0.19	0.08
SD	0.25	0.48	0.33	0.23	0	0.33	0.20	0.43	0.31	0.55	0.38	0.41	0.26	0.60	0.28
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.04	0.07[c]	0.01[c]	0.02	0	0.07	0	0.05	0.06	0.08	0.02	0.03	0.03	0.05	0.01
SD	0.22	0.33	0.10	0.18	0	0.31	0	0.27	0.27	0.35	0.13	0.17	0.18	0.21	0.11
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.01	0.03	0.01	0	0	0	0	0.03	0.02	0.04	0.02	0.02	0.01	0.03	0.01
SD	0.10	0.16	0.10	0	0	0	0	0.16	0.13	0.20	0.13	0.14	0.11	0.18	0.11
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.09[a]	0.33[a,b]	0.16[c]	0.14	0.04	0.27	0.10	0.23	0.12	0.36	0.20	0.20	0.12	0.30	0.19
SD	0.29	0.64	0.41	0.39	0.20	0.51	0.35	0.53	0.32	0.71	0.44	0.47	0.32	0.61	0.42

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

Table 6. Mean counts of golden eagles at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	0.08[b]	0.16	0.19[b]	0.17	0.07	0.16	0.29	0.13	0.08	0.17	0.13	0.11	0.05	0.15	0.14
SD	0.29	0.42	0.43	0.43	0.26	0.44	0.52	0.37	0.31	0.42	0.36	0.34	0.21	0.39	0.38
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.02	0.06	0.02	0.04	0.04	0.04	0.04	0.03	0.01	0.07	0.01	0.01	0.00	0.04	0.00
SD	0.14	0.26	0.23	0.27	0.20	0.21	0.36	0.18	0.09	0.28	0.09	0.11	0.00	0.19	0.00
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	84	85
Mean	0.07[b]	0.16	0.19[b]	0.17	0.11	0.13	0.27	0.12	0.05	0.18	0.14	0.13	0.07	0.17	0.15
SD	0.28	0.42	0.49	0.44	0.32	0.34	0.59	0.39	0.26	0.47	0.42	0.38	0.30	0.41	0.42
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	0.10	0.13[c]	0.03[c]	0.10	0.16	0.11	0.01	0.08	0.07	0.13	0.04	0.08	0.07	0.13	0.05
SD	0.35	0.36	0.20	0.33	0.44	0.32	0.12	0.31	0.28	0.39	0.24	0.33	0.30	0.40	0.26
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.04	0.06	0.09	0.05	0.01	0.04	0.09	0.05	0.05	0.07	0.09	0.08	0.07	0.05	0.12
SD	0.19	0.26	0.40	0.23	0.12	0.20	0.33	0.27	0.22	0.28	0.43	0.34	0.26	0.21	0.50
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.08	0.14	0.10	0.07	0.09	0.04	0.07	0.13	0.08	0.19	0.11	0.13	0.09	0.20	0.09
SD	0.29	0.45	0.34	0.25	0.28	0.20	0.26	0.42	0.30	0.54	0.39	0.44	0.33	0.57	0.36
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.12	0.11	0.15	0.11	0.10	0.09	0.16	0.13	0.13	0.12	0.14	0.09	0.10	0.08	0.09
SD	0.35	0.33	0.38	0.32	0.30	0.28	0.37	0.38	0.38	0.35	0.40	0.33	0.34	0.31	0.33

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

Ferruginous hawks. — Occurrence of ferruginous hawks (Table 8) did not change with respect to time of day or area in breeding 1991, winter 1991-92, breeding 1992, or breeding 1993 ($P > 0.29$ in all cases). Numbers were too small to be analyzed in dry 1991, dry 1992, and winter 1992-93. Proximity to agriculture appeared to have no effect on the abundance of ferruginous hawks.

Rough-legged hawks. — The OTA*period interaction was significant for rough-legged hawks (Table 9) in breeding 1991 ($d = 2.12$, $P = 0.011$) and dry 1992 ($d = 2.09$, $P = 0.004$), indicating that their relative use of OTA and non-OTA sites is influenced by time of day in these seasons. Rough-legged hawk numbers were higher at OTA sites in the afternoon ($d = 0.09$, $P = 0.050$) in breeding 1991 and higher at non-OTA sites in the afternoon and evening (afternoon: $d = 0.14$, $P = 0.012$; evening: $d = 0.07$, $P = 0.024$) in dry 1992. However, these differences only approached Bonferroni-adjusted significance, and there were no diurnal differences within either OTA or non-OTA subset. No variation was found among periods or between areas in any other season. When sites near agriculture were not included in the analysis, differences between and among periods and areas were eliminated in dry 1992 ($P > 0.16$ in all cases); results from breeding 1991 were unaffected.

Military Training. — Of 192 pairs of counts conducted in the 1992-93 non-breeding seasons combined (dry 1992 and winter 1992-93), military training was present at the OTA member of 20 pairs. The null hypothesis that military activity does not affect raptor use of the OTA could not be rejected at the 0.05 level, but we tended to see raptors less frequently at only the OTA sites ($n = 0$) than at only non-OTA sites ($n = 4$) during periods of military training ($G^2_1 = 3.68$, $P = 0.06$) (Fig. 5a). During the 1993 breeding season, 46 of 96 pairs of counts occurred when military activity was recorded at the OTA member of the pair. Raptors were present significantly more often at only non-OTA sites ($n = 8$) than only at OTA sites ($n = 0$) when military training was present ($G^2_1 = 5.68$, $P = 0.02$) (Fig. 5b). During counts with no military activity, raptors were recorded at only the non-OTA site on 15 occasions compared to 8 times at the OTA site only.

In all seasons, regardless of military activity, the mean number of raptors recorded was higher (or equal in the case of breeding 1992, no military activity) on the non-OTA side of our paired points

Table 10. Mean counts of all raptor species at OTA and non-OTA paired sites in the presence or absence of military activity (MA) during breeding 1991, breeding 1992, breeding 1993 and the combined non-breeding (dry and winter) seasons in 1991 and 1992. [* = a significant difference (P < 0.0125)] between mean raptor counts in that season).

		Paired sites WITH MA		Paired sites WITH NO MA	
Season		OTA	NON-OTA	OTA	NON-OTA
Breeding 1991	N	11	11	32	32
	MEAN	2.04	2.23	1.34	1.67
	SD	1.35	1.47	1.25	1.23
Breeding 1992	N	17	17	32	32
	MEAN	0.59*	0.68	1.03*	0.99
	SD	1.12	0.92	0.75	0.83
Breeding 1993	N	17	17	32	32
	MEAN	0.65*	1.41	1.49*	1.58
	SD	0.72	1.13	1.14	1.05
Non-breeding 1991	N	17	17	32	32
	MEAN	0.25*	1.06	0.58*	0.80
	SD	0.43	1.36	0.34	0.67
Non-breeding 1992	N	9	9	32	32
	MEAN	0.11*	0.94	0.29*	0.45
	SD	0.33	1.33	0.25	0.38

Table 7. Mean counts of Swainson's hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	0.09	0.10	0.22	0.10	0.06	0.09	0.17	0.16	0.12	0.11	0.25	0.11	0.08	0.03	0.22
SD	0.34	0.38	0.82	0.36	0.23	0.28	0.52	0.64	0.39	0.43	0.95	0.63	0.31	0.18	1.05
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.17	0.03	0.01	0.00	0.00	0.01	0.00	0.11	0.27	0.04	0.02	0.02	0.02	0.04	0.00
SD	2.18	0.20	0.15	0.00	0.00	0.12	0.00	1.59	2.74	0.24	0.18	0.16	0.15	0.24	0.00
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	84	85
Mean	0.01	0	0.02	0	0	0	0	0.02	0.02	0	0.03	0.02	0.02	0	0.05
SD	0.15	0	0.23	0	0	0	0	0.20	0.19	0	0.29	0.23	0.22	0	0.34
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	0.07	0.05	0.03	0.04	0.03	0.04	0.04	0.06	0.09	0.06	0.02	0.03	0.07	0.02	0.01
SD	0.31	0.25	0.16	0.22	0.17	0.27	0.20	0.26	0.37	0.24	0.13	0.20	0.30	0.15	0.11
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0	0.03	0	0	0	0	0	0.02	0	0.05	0	0.01	0	0.03	0
SD	0	0.23	0	0	0	0	0	0.14	0	0.29	0	0.14	0	0.24	0
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0	0	0.01	0	0	0	0.01	0	0	0	0	0	0	0	0
SD	0	0	0.07	0	0	0	0.12	0	0	0	0	0	0	0	0
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.14	0.10	0.15	0.04	0.01	0.01	0.09	0.18	0.21	0.14	0.18	0.14	0.14	0.13	0.14
SD	0.80	0.41	0.57	0.19	0.12	0.12	0.28	0.76	1.00	0.51	0.69	0.62	0.64	0.50	0.71

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

Table 8. Mean counts of ferruginous hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	190	204	70	69	65	355	120	120	115	253	86	86	81
Mean	0.08	0.08	0.09	0.10	0.07	0.10	0.14	0.07	0.08	0.08	0.06	0.09	0.12	0.07	0.07
SD	0.32	0.31	0.34	0.35	0.31	0.30	0.43	0.31	0.33	0.32	0.27	0.33	0.39	0.30	0.31
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.02	0.01	0.00	0.02	0.06[a]	0.01	0.00	0.00	0.00[a]	0.00	0.00	0.00	0.00[a]	0.00	0.00
SD	0.14	0.07	0.00	0.15	0.23	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	84	85
Mean	0.02	0.01	0.02	0.01	0.01	0	0.01	0.02	0.03	0.01	0.02	0.02	0.03	0.01	0
SD	0.18	0.07	0.16	0.10	0.12	0	0.12	0.17	0.20	0.09	0.18	0.15	0.24	0.11	0
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	0.04	0.08	0.05	0.05	0.04	0.06	0.04	0.06	0.04	0.09	0.06	0.04	0.03	0.06	0.03
SD	0.20	0.29	0.25	0.21	0.20	0.23	0.20	0.27	0.20	0.32	0.27	0.22	0.18	0.28	0.18
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.01	0.01	0	0.01	0.01	0.01	0	0	0.01	0	0	0	0	0	0
SD	0.10	0.07	0	0.10	0.12	0.12	0	0	0.09	0	0	0	0	0	0
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.08	0.06	0.07	0.06	0.07	0.06	0.06	0.08	0.08	0.07	0.08	0.08	0.09	0.08	0.06
SD	0.27	0.24	0.27	0.24	0.26	0.23	0.23	0.28	0.28	0.54	0.30	0.27	0.29	0.28	0.24

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

Table 9. Mean counts of rough-legged hawks at OTA and non-OTA sites and at all Integrated Study Area (ISA) sites combined during 7 seasons. The "non-OTA sites without ag" category excludes all non-OTA sites within 2 km of agriculture. (M = morning; A = afternoon; E = evening).

	All ISA sites			OTA sites				Non-OTA sites				Non-OTA sites without ag			
Season	M	A	E	Total	M	A	E	Total	M	A	E	Total	M	A	E
Breeding 1991															
N	190	189	180	204	70	69	65	355	120	120	115	253	86	86	81
Mean	0.01	0.05	0.05	0.07	0.01	0.10	0.09	0.02	0.01	0.02	0.03	0.02	0.01	0.02	0.04
SD	0.10	0.25	0.26	0.29	0.12	0.35	0.34	0.16	0.09	0.16	0.21	0.18	0.11	0.15	0.25
Dry 1991															
N	190	188	189	208	70	69	69	359	120	119	120	257	86	85	86
Mean	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
SD	0.10	0.07	0.07	0.00	0.12	0.00	0.00	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.00
Winter 1991-92															
N	189	186	189	210	70	70	70	354	119	116	119	255	86	84	85
Mean	0.15	0.15	0.21	0.15	0.07	0.17	0.21	0.18	0.19	0.14	0.20	0.14	0.20	0.06	0.15
SD	0.45	0.46	0.49	0.45	0.31	0.51	0.51	0.48	0.51	0.44	0.48	0.44	0.55	0.24	0.45
Breeding 1992															
N	190	190	190	210	70	70	70	360	120	120	120	258	86	86	86
Mean	0.26	0.24	0.14	0.25	0.26	0.34	0.16	0.19	0.27	0.18	0.12	0.16	0.15	0.14	0.17
SD	0.68	0.66	0.48	0.63	0.58	0.74	0.56	0.60	0.73	0.60	0.44	0.51	0.50	0.53	0.51
Dry 1992															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.05	0.07	0.04	0.01	0.03	0	0	0.08	0.06	0.12	0.06	0.04	0.01	0.08	0.02
SD	0.21	0.36	0.19	0.10	0.17	0	0	0.33	0.24	0.45	0.24	0.26	0.11	0.41	0.15
Winter 1992-93															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.20	0.21	0.17	0.14	0.16	0.21	0.06	0.23	0.23	0.21	0.24	0.17	0.17	0.17	0.15
SD	0.50	0.46	0.46	0.39	0.44	0.45	0.23	0.51	0.53	0.47	0.54	0.41	0.44	0.41	0.39
Breeding 1993															
N	189	189	189	210	70	70	70	357	119	119	119	258	86	86	86
Mean	0.08	0.16	0.15	0.12	0.06	0.14	0.16	0.14	0.09	0.17	0.15	0.11	0.07	0.14	0.12
SD	0.27	0.50	0.55	0.42	0.23	0.43	0.53	0.48	0.29	0.54	0.56	0.40	0.26	0.53	0.36

[a] Morning/afternoon comparison: $P < 0.01$
[b] Morning/evening comparison: $P < 0.01$
[c] Afternoon/evening comparison: $P < 0.01$
[d] OTA/non-OTA comparison: $P < 0.01$
[e] OTA/non-OTA comparison in morning period: $P < 0.005$
[f] OTA/non-OTA comparison in afternoon period: $P < 0.005$
[g] OTA/non-OTA comparison in evening period: $P < 0.005$
[h] Morning/afternoon comparison at OTA sites: $P < 0.005$
[i] Morning/evening comparison at OTA sites: $P < 0.005$
[j] Afternoon/evening comparison at OTA sites: $P < 0.005$
[k] Morning/afternoon comparison at non-OTA sites: $P < 0.005$
[l] Morning/evening comparison at non-OTA sites: $P < 0.005$
[m] Afternoon/evening comparison at non-OTA sites: $P < 0.005$

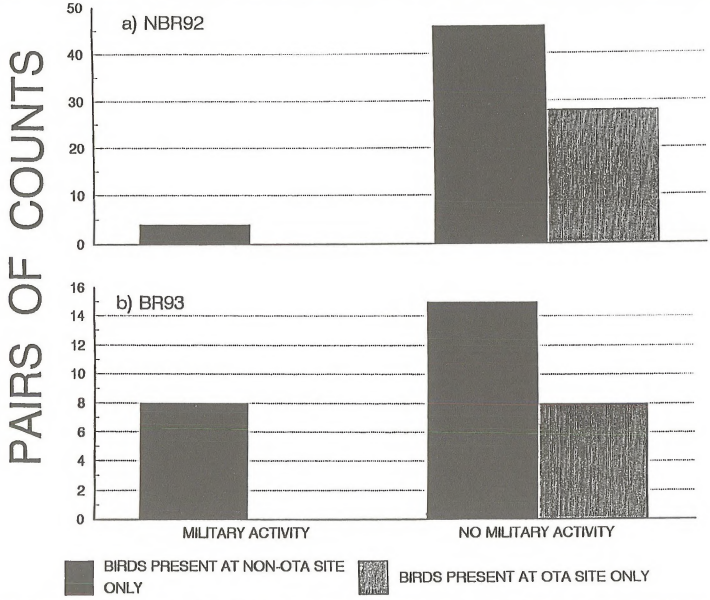

Fig. 5. Occurrence of raptors at OTA and non-OTA sites during simultaneous counts of paired sites in the integrated study area in the presence and absence of military activity during the 1992-93 non-breeding seasons (a) and the 1993 breeding season (b).

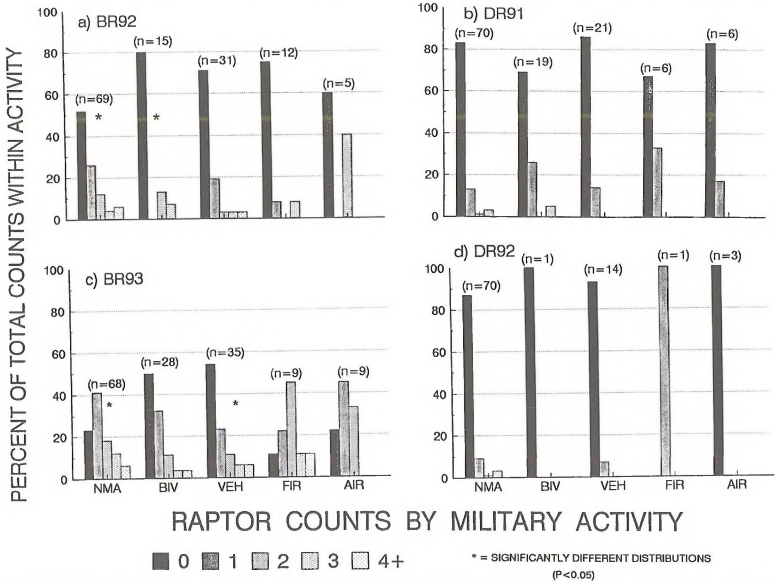

Fig. 6. The percentage of zero, 1, 2, 3, and 4 or more raptors counted on OTA sites with no military activity and sites where bivouacs (BIV), vehicles (VEH), firing (FIR), or air traffic (AIR) were recorded within 3 km of site center and within a 3-hr period before or during the observation period for the 1992 breeding season (a), 1991 dry season (b), 1993 breeding season (c), and 1992 dry season (d).

than in the OTA (Table 10). The only difference to approach the Bonferroni-adjusted significance level ($P < 0.0125$) was in breeding 1993 when military activity was present ($P = 0.05$). Acknowledging that there are usually more raptors outside the OTA, we then examined mean raptor counts among the OTA members of the pairs for impact by military training. We found significantly lower counts in the presence of military activity in 2 of 3 breeding seasons and in each of the 1991-92 and 1992-93 combined non-breeding seasons (breeding 1992: $Z = -2.60$, $P = 0.0125$; breeding 1993: $Z = -2.85$, $P = 0.006$; non-breeding 1991-92: $Z = -2.94$, $P = 0.005$; non-breeding 1992-93: $Z = -2.76$, $P = 0.009$). Raptor numbers in breeding 1991 tended to be higher during training than when no training was taking place, but the difference was not significant at the Bonferroni-adjusted level ($Z = 2.05$, $P = 0.05$).

To assess whether differences in numbers of raptors observed between OTA sites with military activity and OTA sites without military activity was due to better habitat at the no military activity sites, the non-OTA sites of the paired points group were also compared. Because OTA and non-OTA sites were paired to control for vegetation differences, a similar result in the non-OTA groups could be expected if habitat was the overriding influence. There were no significant differences in any season in the comparison of non-OTA sites with military activity on its OTA paired site and non-OTA sites with no military activity on its OTA paired site ($P > 0.10$) (Table 10).

We tended to record more zero raptor counts in the presence of bivouacs and vehicles during both the 1992 and 1993 breeding seasons (Figs. 6a, 6c), although this trend was only significant for bivouacs in 1992 (bivouacs: $G^2_4 = 10.34$, $P = 0.035$; vehicles: $G^2_4 = 4.05$, $P = 0.399$) and vehicles in 1993 (bivouacs: $G^2_4 = 7.09$, $P = 0.131$; vehicles: $G^2_4 = 9.98$, $P = 0.041$). Firing and air traffic did not seem to affect the frequency distribution of raptors in either breeding season ($P > 0.22$ in all cases), but numbers were very low. Dry seasons always had a high frequency of zeros counts in the SRBOPA regardless of OTA status. Similarly, within the OTA high numbers of zero counts were recorded, regardless of the presence or type of military training ($P > 0.20$ in all cases) (Fig. 6b, 6d).

Raptor Detections and Habitat

Eighty-nine sites were classified as *Artemisia*-associated shrub, 15 as *Atriplex*-associated shrub, 69 as grass/exotic annual, and 7 as shrub mosaic.

Time of Day. — No interaction was found between habitat class and time of day for any species in any season, indicating that raptors and ravens do not adjust their use of different habitat types depending on time of day. Several groups, however, did exhibit significant associations with different habitats regardless of diurnal period. In breeding 1991, ravens ($d = 2.88$, $P = 0.006$) and harriers ($d = 0.46$, $P = 0.006$) were recorded significantly more often at sagebrush-associated shrub sites than in any other habitat type. Harrier use of different habitats was also significant in breeding 1993 ($d = 0.42$, $P = 0.007$), and raptors as a group showed significant differential associations with habitats in all 3 breeding seasons (1991: $d = 1.09$, $P < 0.001$; 1992: $d = 0.73$, $P < 0.001$; 1993: $d = 0.92$, $P = 0.001$) as well as in winter 1991-92 ($d = 0.63$, $P < 0.001$). In all cases, detections were highest at sagebrush-associated shrub sites and fairly evenly distributed among the remaining habitat types.

Habitat Use v. Availability. — Within the OTA, raptors were detected at sites whose habitat composition differed from the habitat composition of all sites only in the 1991 dry season. Both golden eagles specifically ($d = 36.75$, $P = 0.008$) and raptors as a group ($d = 35.94$, $P = 0.008$) were more abundant at sites that contained more high density sagebrush, medium density shadscale, and medium density winterfat and less native perennial grasses, cheatgrass, and exotic annuals than OTA sites in general.

Outside the OTA in both winter seasons (1991-92: $d = 43.07$, $P < 0.001$; 1992-93: $d = 43.00$, $P < 0.001$), golden eagles were present at sites with disproportionately high coverage of high density sagebrush, medium density sagebrush, and medium density winterfat relative to all available sites. Sites at which we recorded eagles in these seasons also had relatively lower coverage of Russian thistle/highly disturbed shrubland and cheatgrass/disturbed grassland.

In the 1993 breeding season ($d = 42.96$, $P = 0.004$), we tended to see red-tailed hawks at sites with

more high density sagebrush, medium density sagebrush, medium density shadscale, and medium density winterfat than is generally available at non-OTA sites. These sites also were characterized by lower proportions of Russian thistle/disturbed shrubland and cheatgrass/disturbed grassland.

Agricultural Lands. — Of 119 non-OTA sites, 33 had agriculture, as determined by the GIS, within 2 km of the center of the site. We detected more birds at ag sites than at non-ag sites in every season. Significant differences were found in all seasons. Breeding 1991: ravens (d = 3.49, $P < 0.001$) and Swainson's hawks (d = 0.21, P = 0.005) in the afternoon. Dry 1991: red-tailed hawks in the morning (d = 0.15, $P < 0.001$) and ravens in all periods (d = 2.40, $P < 0.001$). Winter 1991-92: ravens in the morning (d = 2.54, $P < 0.001$). Breeding 1992: ravens (d = 2.87, $P = 0.001$) and northern harriers (d = 0.36, P = 0.005) in all periods and rough-legged hawks in the morning (d = 0.42, $P < 0.004$). Dry 1992: ravens in all periods (d = 1.70, $P < 0.001$) and harriers (d = 0.13, $P < 0.001$) and rough-legged hawks (d = 0.10, $P < 0.001$) in the morning. Winter 1992-93: rough-legged hawks in all periods (d = 0.30, P = 0.003), prairie falcons in the morning (d = 0.17, P = 0.002) and afternoon (d = 0.22, P = 0.005), and ravens in the morning (d = 2.29, P = 0.002). Breeding 1993: harriers in all periods (d = 0.46, P = 0.002) and ravens in the morning (d = 2.71, P = 0.001) and afternoon (d = 2.56, $P < 0.001$). Ferruginous hawks and golden eagles did not seem to be influenced by the presence or absence of nearby agriculture.

DISCUSSION

Seasonal patterns and diurnal differences

Differences in diurnal activity and seasonal abundance patterns were detected at some point in the study for every species analyzed. Very few within species differences proved consistent over time, making conclusions difficult. Being a natural system, many factors influencing the birds are uncontrolled and unknown. Such unknown quantities as natural variability in a bird's activity pattern based on its foraging success, the presence of a dependent and its nutritional needs, or just the daily weather patterns (Marzluff et al. 1992) may confound our results in ways we have yet to discern. The influence of yearly weather patterns, mainly its effect on prey species, could also be a confounding factor. The 3 years of this study have had fairly different weather patterns for each breeding season (Fig. 7). Spring 1991 was cool and wet with good prey levels, whereas spring 1992 was hot and dry. The drought of 1992 had quite marked effects on the prey condition, and 1993 was a poor year for squirrels (Van Horne et al. 1992, this volume).

Despite these many uncontrolled and highly variable factors, our results did suggest a few trends. Ravens were more abundant in the mornings during the breeding seasons and more abundant in the evenings during the non-breeding seasons. Engel et al. (1992) reported that ravens in southwestern Idaho consistently depart night-time roosts early in the morning, though arrival at roosts varied depending on time of year . Ravens tended to return earlier to roost sites from March to July, our breeding season, and later in all other months. The higher numbers we recorded in evening or morning, depending on the season, probably reflects the seasonal pattern in travel times to and from roost sites. Our tendency to see fewer ravens in the afternoon supports Engel and Young's (1992) conclusions that once a raven left a roost, it does not spend the day flying among foraging sites but remains at a single foraging area for the rest of the day.

Golden eagles were observed more in afternoons than in either morning or evening periods. This diurnal pattern may be explained by golden eagles' use of thermals and soaring. Eagles may remain perched, and therefore both localized and less likely to be seen, until thermal activity increases. As soaring conditions improve, so does eagle visibility, until they soar so high we are once again unable to see them. It would be interesting to know how often eagles soar so high we lose the ability to detect them and at what times of day that is most likely to occur.

The fact that northern harriers were seen in lower numbers during the afternoon in all seasons is not as readily understandable as the previous trends. These results may be tied to activity patterns of their prey; however, it seems unlikely that this is the total answer as their prey base varies throughout the year. Specific investigations of harrier behavior would probably be necessary to confirm or reject the presence of this trend.

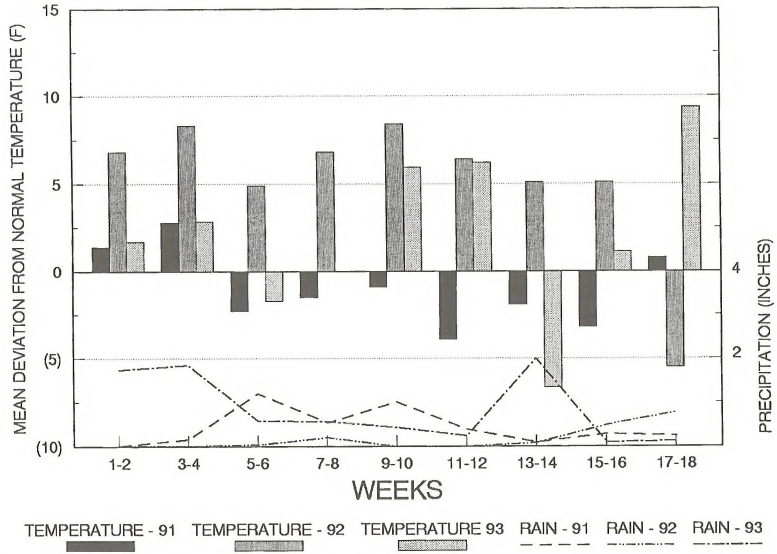

Fig. 7. Trends in precipitation and temperature deviation from normal at Boise Air Terminal in the 1991, 1992, 1993 breeding seasons. Weeks 1-2 = 9 March to 22 March; 3-4 = 23 March to 5 April; 5-6 = 6 April to 19 April; 7-8 = 20 April to 3 May; 9-10 = 4 May to 17 May; 11-12 = 18 May to 31 May; 13-14 = 1 June to 14 June; 15-16 = 15 June to 28 June; and 17-18 = 29 June to 15 July. Weather data source: National Weather Service, Boise, Idaho.

Military Training

Military activity could influence raptors in the OTA in several ways. The first is the immediate impact of training on raptor use of the OTA, i.e., whether birds are more or less likely to use the OTA while training is actually occurring. We tried to answer this question from 2 perspectives. First, our raptor presence/absence analyses compared differences between relative abundance inside and outside the OTA during periods of training as well as periods of no training. It is important to remember that this analysis considers pairs of sites, and that our pairings are designed to control for differences in vegetation, weather, and geographic factors between the OTA and the rest of the ISA. Thus far, we have found a significant negative impact on raptor abundance by military training in every breeding season. We also compared OTA counts during training with OTA counts that had no training to assess immediate impacts of training; again we found lower raptor numbers in the presence of military activity in almost all seasons. These results suggest that the short-term disturbances of concurrent military activity (e.g., noise, traffic) may directly affect raptor abundance while that activity is taking place and for a period of time following that activity — the time it takes for a raptor, once disturbed from an area to return to the same site.

The second possible effect of training is historical, i.e., whether past military activity somehow affects the present-day raptor use of the OTA even when no training is taking place. The comparison of abundance on and off the OTA regardless of concurrence of training, controlling for the potential influence of time of day, was designed to test for such long-term effects of military training, because training is an activity exclusive to the OTA. Our results, which have shown lower numbers of birds inside the OTA than outside for several species in certain times of day, are not overwhelmingly conclusive or consistent, and the historical effect of training activities may be confounded by other long-term factors such as grazing and fires.

The pattern of fewer birds on the OTA than off during military training in the breeding season, with no such difference in the non-breeding seasons, mimics the results from 1991-92 and appears to point to a consistent trend: military activity has, thus far, influenced raptor abundance more strongly in the breeding seasons than at other times of year. Several factors are involved here. First, most of the intensive training during our study has taken place from May-July, corresponding to most of our breeding season. During this time, training is characterized by large numbers of personnel and vehicles, and by intensive activities such as bivouacs, tank maneuvers, and frequent artillery firing. Training activities in the rest of the year usually involve far fewer people, and vehicles are typically limited to maintenance and low-level training. An exception to this occurred in August 1993, when IDARNG staged a large-scale training exercise similar to 1992's "Operation Bold Shift;" it will be interesting to examine data from dry 1993 in light of this late-season activity. Second, dry season counts have been very low in every year of the study, with large proportions of zero counts for most raptors. Winter season raptor counts also tend to be lower than breeding season counts. Military training therefore seems to have less influence on raptor abundance simply because there are fewer raptors to be affected, either positively or negatively. From a management perspective, this is an important factor to consider when planning training activities to minimize impact on raptors.

In addition to the timing, the type of military training probably plays a substantial role in determining its impact on raptors. Although information about particular types of training is somewhat meager (dividing an already-small data set of military training days among 4 types of activity can yield sparse samples), preliminary analyses point to reduced raptor abundance near bivouacs and vehicle traffic, whereas air traffic, artillery, and tank firing have so far shown no such effect. Air traffic, which might be expected to have a relatively low impact on nesting birds, is not restricted to the OTA; areas outside the OTA are subject not only to IDARNG helicopters moving to and from the OTA, but also to low-flying jets from nearby Mountain Home Air Force Base. We hope in the future to obtain digital data about other types of activity such as tank maneuvers similar to the bivouac information that was so useful to us this year. However, rigorous analyses of the impacts of different training types will always be limited by small sample sizes, and will be better addressed by Study 2's direct observations on ranges and at bivouac sites.

Habitat Use

The large scale at which our sites are sampled (314 ha per site) precludes assessment of fine-

grain habitat use by raptors. In fact, such a fine-grain analysis may be inappropriate for the scale at which most foraging raptors use their environment. The best we can do is to quantify the general types of habitat in which we are likely to see raptors. This we have done both by measuring abundance at sites grouped by a single dominant habitat class, and by comparing the habitat composition of sites used by raptors with that of all of our sites. Both sets of results indicate that some species, notably harriers and golden eagles, are more likely to be detected at sites characterized by sagebrush and winterfat than at sites dominated by grass and exotic annuals. Although this is not surprising, it may lead to additional questions. Vegetation, precipitation, soils, and fire history seem to differ across the study area, with more mesic shrubs such as sagebrush present in the northwest, and shadscale, other xeric shrubs, and disturbed grasslands more common in the southeast. With such a clustering of habitat types in space, it becomes difficult to determine what drives the use of different sites by raptors; if we see more golden eagles in the northwest, for example, is it because they prefer sagebrush, or because the sagebrush sites happen to be near preferred nesting strata in the canyon?

Agricultural lands continue to play a role in determining distribution of raptors and ravens in the SRBOPA. Although sites near agriculture clearly must be excluded from any OTA/non-OTA comparisons, at least for those species whose distributions are strongly linked to agriculture, we believe that including agricultural lands in other analyses is justified by the heavy use of these lands by some raptors and ravens. Understanding the importance of altered habitats in the landscape is critical to making informed management decisions.

PLANS FOR NEXT YEAR

Point counts will continue as in 1991-93, through 15 July 1994. No major changes in methods are planned. We will be running new similarity indices using the GIS database habitat information to test the validity of our original paired sites. We also will tackle the question of behavioral differences in terms of diurnal periods, season, and military activity (question 4 of the original study plan Watson & Strickler 1990). Integrating our results with those of other studies will have an increasing focus, as will extended analyses comparing seasons from different years as our study nears completion. More extensive analyses of raptor habitat use also will be performed in the coming year.

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Appendix A. Species totals and total counts for 1991 breeding, 1991 dry, 1991/92 winter, 1992 breeding, 1992 dry, 1992/93 winter, and 1993 breeding seasons.

Species	91 Br.	91 Dry	91/92 Winter	92 Br.	92 Dry	92/93 Winter	93 Br.
Total counts	559	567	564	570	567	567	567
All species	2,291	1,047	1,827	1,835	957	1,329	1,791
All raptors	816	254	484	585	201	341	791
Common raven	1,475	793	1,343	1,250	756	988	1,000
Northern harrier	226	47	117	148	29	69	228
Prairie falcon	163	24	54	72	17	49	114
Red-tailed hawk	92	33	39	56	23	9	110
Golden eagle	80	19	80	49	35	59	70
Swainson's hawk	77	40	6	28	6	1	72
Ferruginous hawk	47	5	8	33	3	0	40
Rough-legged hawk	21	4	95	121	30	111	74
Short-eared owl	21	1	0	10	2	5	1
American kestrel	13	8	8	8	20	5	23
Burrowing owl	5	3	0	1	0	0	3
Turkey vulture	5	16	0	7	8	0	6
Bald eagle	0	0	10	2	0	6	1
Cooper's hawk	2	0	1	0	1	0	0
Sharp-shinned hawk	1	1	2	0	3	0	0
Northern goshawk	0	0	0	0	1	0	1
Unidentified	63	53	64	50	23	27	48
Unidentified (%)	3.0	5.0	3.5	3.0	2.4	2.0	2.7

Patterns of Density, Reproduction, and Survival in Townsend's Ground Squirrels

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ANNUAL SUMMARY

*During our third field season, January through June, of a planned 4-yr study, we continued to collect information to describe differences in population processes for Townsend's ground squirrels (**Spermophilus townsendii**) among habitats and among years. We extended our collection of basic demographic data from our 20 study sites that differ in vegetation type, fire history, and history of tracking by armored vehicles. To aid in the interpretation of burrow entrance counts as an index of population density, we continued to investigate patterns of burrow usage and burrow entrance phenology.*

As a result of the 1992 drought and prolonged low temperatures and snow cover in 1993, adult densities were uniformly low as compared to previous years. We captured 296 individual juveniles across all sites, as compared to 743 in 1992. Average per capita production of trappable offspring across sites with females present was 0.8, as compared to 1.8 in 1992. Sex ratios continued to be significantly female-skewed in higher density populations, but low adult female persistence through the torpid period led to an average sex ratio across populations of 45.2%, as compared to 66.0% and 58.7% in the 2 previous years. Juvenile persistence through the torpid period was <0.6%, and we think almost the entire cohort of last year's juveniles died.

Experimental tracking by armored vehicles at the end of the 1992 above-ground season did not produce any apparent differences in ground squirrel density.

Constant addition of food to 2 sites during the active season resulted in substantially higher densities, but per capita production increased only slightly.

OBJECTIVES

1. To continue to make significant progress toward the goals of determining whether Townsend's ground squirrel densities, survival rates, and productivity differ:
   a) among habitat types.
   b) between areas that have been subjected to experimental tracking by armored vehicles and those that have not.
   c) between burned and unburned areas.
   d) between burned areas that have been seeded and those that have not been seeded.

2. To evaluate the role of food in determining density, mass, and reproduction by adding food experimentally.

3. To aid the interpretation of hole counts as indices of population density by determining patterns of hole use and by summarizing hole phenology.

METHODS

Study Sites

Sites are identical to those described previously (Van Horne et al. 1992), except that 2 sites had food added during the 1993 active season (Table 1, Fig. 1).

Macroclimate

We used weather records from the Boise, Idaho Airport (National Climate Data Center) to compare 1991-93 patterns of temperature and precipitation with long-term averages. This weather station is 25.6 km from our closest trapping site (10a), and has the most complete set of records of any nearby weather station. A general inspection of the records indicates to us that the study area follows the same temperature and precipitation patterns, although it is generally drier.

Density Estimation

As in 1992 (Van Horne et al. 1992), we estimated density by dividing estimates of population size by the estimated area covered by the trapping grid. Also as in 1992, assessment line trapping was used to make area estimates, but with 2 differences. First, because sample sizes were much smaller for 1993 than for 1992, it was necessary to pool data from sexes to obtain area estimates by age class and habitat type (shrub vs. burn). Second, we computed area estimates for supplemental feeding sites (7a and 8a) separately from other burn sites, as we expected that the presence of excess food on the trapping grid would influence the area from which animals were drawn to traps.

We computed population estimates for 1992 juveniles and 1993 adults (and attempted for 1993 juveniles) using newly developed techniques for open population models. As was done for adults in 1992 (Van Horne et al. 1992), we used the special case of Jolly-Seber models known as "death only" or "no-recruitment" to compute estimates of numbers of juveniles at time of emergence from natal burrows, and adults at time of emergence from hibernation. However, because of small sample sizes and/or low recapture rates,

Table 1. Site pairs for sampling of Townsend's ground squirrels in the Snake River Birds of Prey Area.

Habitat Type	
Winterfat outside the Orchard Training Area (OTA)	1a, 1b
Sagebrush outside the OTA	2a, 2b
Sagebrush/Winterfat outside the OTA	3a, 3b
Burned Sagebrush inside the OTA	4a, 4b
Sagebrush inside the OTA	5a, 5b
Burned Winterfat outside the OTA	6a, 6b
Burned Sagebrush/Winterfat outside the OTA	7b, 8b
Burned Sagebrush/Winterfat outside the OTA with food added	7a, 8a
Sagebrush inside the OTA tracked in 1992	9a, 9b
Burned sagebrush inside the OTA tracked in 1992	10a, 10b

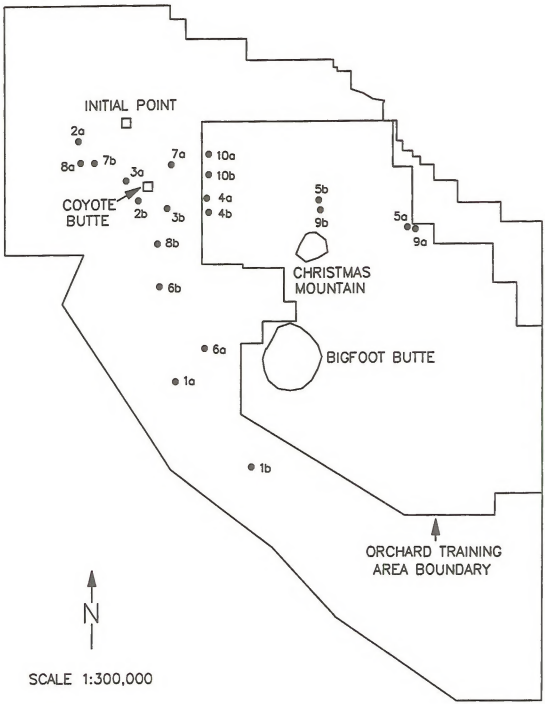

Fig. 1. Study site locations in the Snake River Birds of Prey Area (SRBOPA) near Boise, Idaho, 1993 (see Table 1 for site types).

we were unable to use Program JOLLY (Pollock et al. 1990:34-36) model A' to compute population estimates on these data sets. Instead, we modified code from a Proc NLIN (SAS Institute Inc. 1990) program written by Burnham (1989) that enabled us to compute estimates from more constrained models (i.e., fewer parameters) than model A'. The basic procedures for model development and selection were similar to those advocated by Burnham and Anderson (1992) and Lebreton et al. (1992) for survival rate estimation, except that here the main goal was estimation of population size. We examined several models (generally about 10) for each site on which ≥20 animals were caught. We constructed models by forcing constraints on survival and/or capture rates as a function of time, and attempted combinations of time-specific, constant, linear, and quadratic models. (See Appendix A for more details on model theory and construction). "Best" models were selected based on at least 3 criteria: (1) low AIC (Akaike's Information Criterion, Akaike 1973, 1985), (2) reasonable parameter estimates, especially of population size but also of survival and capture rates, and (3) model parsimony (fewer parameters), because of the better precision of the estimates from these models.

In some cases, no estimates of population size were possible using modelling techniques because of small sample sizes. However, we felt that we could improve upon the Minimum Number Alive (MNA; equal to the total animals captured) reported last year for juveniles (Van Horne et al. 1992) by computing a pooled estimate (average) of the proportion of animals captured (based on sites within the same general habitat type, burn vs. shrub) from sites where modelling was possible, and expanding the MNA by this proportion.

Retention of Passive Integrated Transponders

The analyses we used to estimate survival and population densities assume that marked individuals retain their marks. A severe violation of this assumption could bias parameter estimates. We previously reported that retention of passive integrated transponder (PIT) tags was probably ≥95% within a year, and possibly 100% between 2 years (Schooley et al. 1993). We have updated these results with within-year PIT loss for 1992 and 1993, and estimates of between-year loss for 1992-1993. These estimates were based on data from the 6 behavioral sites (1a, 3b, 4a, 5b, 9b, 10a) where we continue to dye squirrels. The between-year rates were based mostly on adults, because we recovered so few juveniles in 1993.

In general, we have followed previously described methods (Schooley et al. 1993). We calculated within-year rates of tag loss and then adjusted these for different probabilities of dye loss. We examined data for 4 sites (4a, 5b, 9b, 10a) in 1992 to obtain a general estimate of the average probability of dye loss. For 1992, we estimated within-year rates of tag loss separately for the 4 sex-age classes and then computed a 95% CI for the mean rate of these classes (using an asymmetric confidence interval based on the lognormal distribution). In 1993, data were too sparse to estimate within-year loss rates separately for sex-age classes. We estimated between-year PIT loss from those squirrels captured in 1993 with dye marks retained from 1992. We computed a 95% profile-likelihood CI for the between-year rates.

Hole Counts

To evaluate the utility of densities of ground squirrel holes for predicting densities of ground squirrels, we censused ground squirrel holes on our 20 study sites between 8 and 13 June 1993. With assistance of personnel from Study 5, we counted all holes on the 4.5-ha trapping grids. We classified assumed ground squirrel holes as either active or inactive, based on animal sign, with active holes being those we believed were used by a ground squirrel within the past several weeks. We also categorized each hole as high certainty or low certainty, which referred to the level of confidence the observer had when assigning an activity class. Therefore, we used 4 classes for holes: active high, active low, inactive high, inactive low.

To examine relationships between densities (number/ha) of holes and ground squirrels, we compared 3 measures of hole density with 1 measure of ground squirrel density. Our measures of holes were TOTAL (sum of counts for all 4 classes), ACTIVE (active high + active low), and POSSIBLY ACTIVE (active high + active low + inactive low). We correlated (Spearman's Rank Correlation Coefficients, R_s) these measures of hole densities with total ground squirrel density, which was the sum of estimates of adult densities at emergence and an index of juvenile densities (MNA estimates/grid area). We performed corre-

lations for all sites combined, and separate analyses for burned sites (n = 10) and shrub sites (n = 10).

Hole Phenology

We randomly selected 50 ground squirrel holes each on 6 trapping grids between 11 and 17 June 1992. We marked, numbered, and recorded the locations of holes from 3 site pairs outside of the OTA, which included sagebrush (*Artemisia tridentata*) habitat (Sites 2a, 2b), burned sagebrush (7a, 7b), and winterfat (*Ceratoides lanata;* 1a, 1b). We attempted to mark active ground squirrel holes based on the criteria used for our extensive hole counts on all sites. However, the early immergence of ground squirrels, together with the rain that occurred in early June, removed most ground squirrel sign at holes and forced us to use less strict criteria; holes that were neither caved in nor filled with debris under these conditions were likely to have been active during the 1992 season. A single observer (RLS) selected most holes (289 of 300) in 1992, and he re-surveyed all holes in early May 1993. He recorded whether each hole was present and its status (active or inactive, high or low certainty). We also had planned to survey holes in early March, but above-average precipitation precluded sampling at this time, except on 1 site (7b). In 1994, we will survey holes again in early May and possibly in early March.

Tracking

On 16 and 17 June 1992, sites 9a, 9b, 10a, and 10b were tracked by an M1 tank driven by IDARING personnel. Total distance driven on each site was calculated to track 33% of the total surface area if tracks did not cross one another. Although there was some track crossing, we minimized this by having the tank make laps back and forth across the site with approximately 30-m radius turns at the ends, then making a series of return laps that straddled or were just outside the previous set of tracks and so forth for the required distance.

Supplemental Feeding Experiment

General Design.—From 4 possible sites, we randomly chose 2 sites as treatments (Sites 7a and 8a) and 2 sites as "controls" (Sites 7b and 8b). The basic design will provide 2 years of pre-treatment data for all sites, and 2 years of data while the treatments are applied. In general, the treatments involved supplying food to the 4.5-ha trapping grids for the entire active season of Townsend's ground squirrels. Specifically, we supplied food every time we trapped the treatment sites, which averaged ca. once per week. Inclement weather sometimes extended the interval between trapping occasions. We supplied food in the afternoon, after we had trapped a site, to reduce the influence of the supplemental food on animal movements and trapping success. We spread the food directly on the ground.

Distribution of Food.—To supply food as evenly as possible to the sample population, we used 126 evenly spaced feeding locations, which we shifted to obtain reasonable spatial coverage. These stations represented the 66 trap locations, and 60 additional locations midway between trap locations (along the established trap lines). On any specific day, we supplied food at 1 of 4 locations relative to each station: 6 m north, 12 m north, 6 m south, or 12 m south. Therefore, each of the 126 stations had 4 feeding locations associated with it. We thus supplied food at each location once every 4 trapping occasions. An example might clarify the design. On Day 1, we would supply food 6 m north of each trap location, and 6 m south of each inter-trap location. On Day 2, we would supply food 6 m south of each trap location, and 6 m north of each inter-trap location. The same pattern was used for Days 3 and 4, except the distance of feeding locations was 12 m from the stations. On Day 5, the cycle was repeated (i.e., same locations as Day 1).

Supplemental Food.—We supplied squirrels with alfalfa pellets and apples. Each of the 126 feeding locations was supplied with 155 g of alfalfa and ca. 35 g of apple (typical wet weight of "standardized" slices). Therefore, on each day that a treatment was applied, we supplied a 4.5-ha grid with 19.5 kg of alfalfa pellets and 4.4 kg of apple.

RESULTS AND DISCUSSION

Macroclimate

We were only able to obtain records through March 1993. Overall, daily mean maximum and minimum temperatures were higher than normal in 1992, similar to normal in 1991 (except for higher temperatures in February), and lower than normal early in the 1993 season (Fig. 2). To assess patterns of total precipitation, we added total rainfall for a given month to that of the previous

2 months. This gives a better indication of soil moisture and growing conditions than 1-month totals. Three-month cumulative precipitation was similar to the 50+ yr mean in 1991 (March and April were a bit drier than normal), and well below the mean in 1992, particularly during May and June (Fig. 3). It was higher than the mean during January-March 1993 (Fig. 3). Persistent snow on the ground inhibits movement of ground squirrels, and increases the difficulty of finding new green growth of grasses. Because we do not have direct measures of snow persistence, we report total cumulative snowfall since October of the previous year as an indication of potential snow levels (Fig. 3). High precipitation levels combined with low temperatures (note that February 1993 mean daily maximum and minimum temperatures are near or below 0 C in Fig. 2) produced higher than normal snowfall in 1993 (Fig. 4) that was persistent on the ground (R. L. Schooley, pers. obs.). Snowfall was lower than normal in 1992; none fell during the ground squirrel active season (Fig. 4).

Livetrapping

During 1993, we captured 872 individual ground squirrels (295 adult males, 281 adult females, 151 juvenile males, 144 juvenile females, and 1 juvenile of unknown sex). We marked 622 individuals with PIT tags (326 new adults, 296 juveniles). We had 2,374 total captures of ground squirrels, which was 28% of the 8,593 captures of squirrels in 1992. We trapped each of our 20 sites on 7-22 days ($\bar{x}$ = 16) from 27 January to 24 June (Table 2). We were unable to access sites 1a and 1b early in the season because of snow cover and muddy roads, and trapped fewer days during juvenile emergence on sites where we did not capture pregnant females. We usually trapped each site for 2 or 3 sessions per day with ca. 66 traps per session on the grid. On 13 sites, we set an additional 18 traps on assessment lines per session (Table 2). Our total effort resulted in 68,068 trap sets. The 58,735 traps set on grid (Table 2) was an 18% increase in effort compared to 1992. We increased overall effort, despite 25 days with unfavorable weather for trapping, by increasing the average number of traps per session, generally trapping sites for 3 sessions per day instead of 2 sessions, and doubling effort (trapping 10 sites per day instead of 5 sites) on days with favorable weather.

Table 2. Trapping effort for Townsend's ground squirrels on 20 study sites at the Snake River Birds of Prey Area, 27 January-24 June, 1993. Trapping grids were 4.5 ha on all sites.

Site	Number of days trapped	Number of sessions	Number of traps set	
			Grid	Assessment line
1a	10	28	1,847	0
1b	9	25	1,648	0
2a	7	16	1,049	0
2b	14	39	2,555	0
3a	11	27	1,754	0
3b	14	39	2,515	0
4a	21	59	3,921	792
4b	20	56	3,704	756
5a	19	51	3,325	702
5b	19	46	3,018	666
6a	13	31	2,033	0
6b	17	44	2,902	576
7a	22	61	4,206	828
7b	21	58	3,807	810
8a	20	57	4,167	774
8b	21	57	3,892	756
9a	16	43	2,842	612
9b	17	45	2,998	621
10a	17	49	3,296	720
10b	17	48	3,256	720
Total	325	879	58,735	9,333

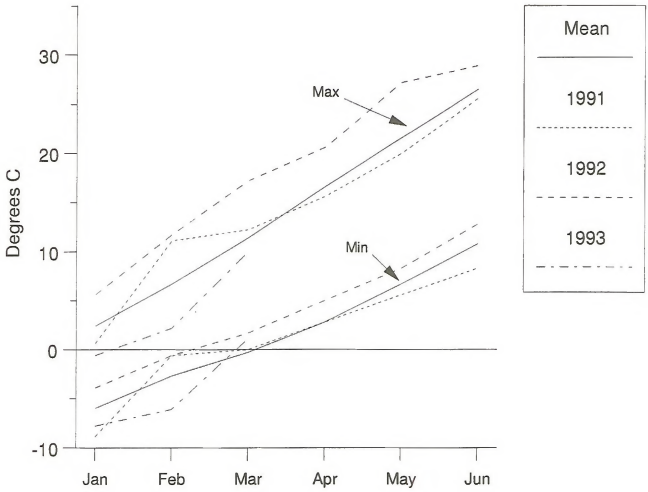

Fig. 2. Mean daily maximum and minimum temperatures at the Boise Airport during the ground squirrel active season in 1991 and 1992, and early in the active season in 1993 (U.S. National Climate Data Center). The means of these values for years 1940-92 are indicated for comparison.

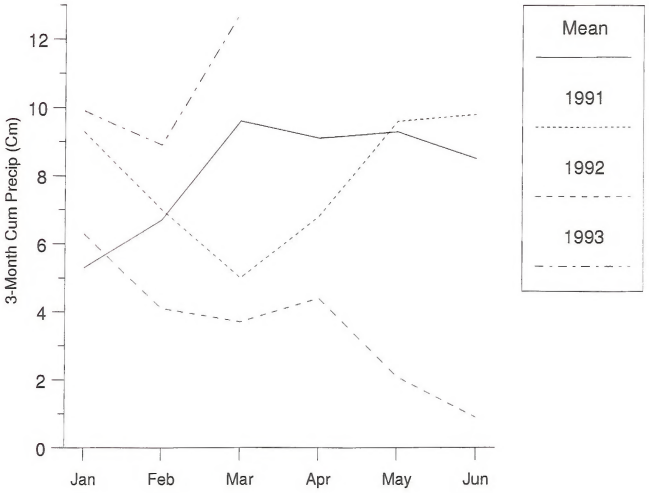

Fig. 3. Three-month cumulative precipitation for each of the months of the ground squirrel active season in 1991 and 1992, and for the first 3 months in 1993, at the Boise Airport (U.S. National Climate Data Center).

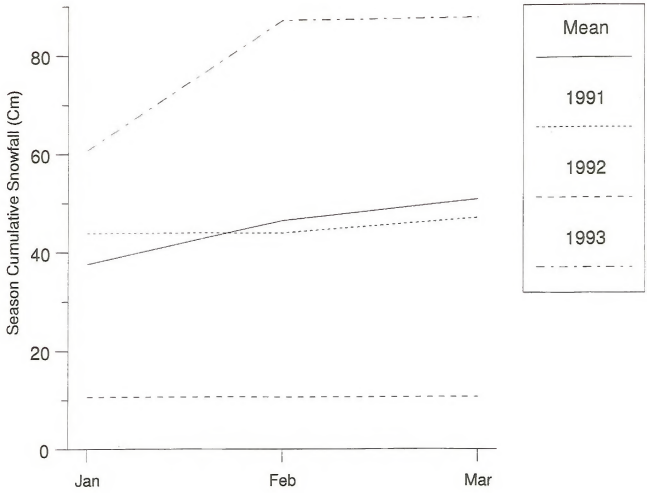

Fig. 4. Total cumulative snowfall for the season beginning in October of the previous year for the years 1991, 1992, and 1993 as reported for the Boise Airport (U.S. National Climate Data Center).

Density Estimation

Table 3 gives density estimates for juveniles in 1992. There were sufficient data to calculate estimates for 10 of the 16 study sites where >1 animal was captured; densities for the remaining sites were estimated using the mean estimated proportion captured from sites in similar habitat types (shrub or burn). It was necessary to combine sexes to estimate overall population size. Therefore we based sex-specific density estimates on the sex ratio of ground squirrels captured, applied to the total population estimate. Generally, we obtained estimates from models with constant survival rate and time-varying capture rates, with the latter either occasion specific or modeled as a quadratic function of time. Estimates of population size, as expected, are substantially higher (range 36-248% increase) than the MNA reported in 1992 (Van Horne et al. 1992), but changes in

Table 3. Density estimates of juvenile Townsend's ground squirrels (1992) for sites in the Snake River Birds of Prey Area, 1992, at emergence from natal burrows. Estimates were obtained directly from modeling techniques except on sites 1a, 1b, 3b, 5b, 7b, and 9b where they were computed from pooled estimates of proportion captured (see text for more complete explanation of estimation methods).

Site	Grid Area (ha)	Strip Width (m)	Adjusted Area (ha)	Sex	MNA*	Proportion of Total	Population Size	Proportion Caught	Density (#/ha)
1a	9.00	37.34	11.38	M	14	0.50	21	0.655	1.84
				F	14	0.50	21		1.84
1b	9.00	37.34	11.38	M	3	0.33	5	0.655	0.44
				F	6	0.67	9		0.79
2a	9.00	37.34	11.38	M	0		0		0.00
				F	0		0		0.00
2b	9.00	37.34	11.38	M	0		0		0.00
				F	0		0		0.00
3a	9.00	37.34	11.38	M	0		0		0.00
				F	0		0		0.00
3b	9.00	37.34	11.38	M	7	0.37	11	0.655	0.97
				F	12	0.63	18		1.58
4a	1.00	47.12	2.16	M	38	0.44	82	0.463	37.96
				F	49	0.56	106		49.07
4b	1.00	47.12	2.16	M	53	0.44	72	0.733	33.33
				F	68	0.56	93		43.06
5a	2.25	37.34	3.51	M	11	0.70	15	0.710	4.27
				F	16	0.30	23		6.55
5b	2.25	37.34	3.51	M	7	0.41	11	0.655	3.13
				F	9	0.59	14		3.99
6a	9.00	47.12	12.05	M	0		0		0.00
				F	0		0		0.00
6b	2.25	47.12	3.89	M	35	0.37	81	0.432	20.82
				F	60	0.63	139		35.73
7a	1.00	47.12	2.16	M	45	0.47	74	0.609	34.26
				F	50	0.53	82		37.96
7b	1.00	47.12	2.16	M	22	0.48	39	0.568	18.06
				F	24	0.52	42		19.44
8a	1.00	47.12	2.16	M	22	0.49	33	0.662	15.28
				F	23	0.51	35		16.20
8b	1.00	47.12	2.16	M	20	0.42	52	0.384	24.07
				F	28	0.58	73		33.80
9a	1.00	37.34	1.89	M	8	0.24	13	0.600	6.88
				F	25	0.76	42		22.22
9b	2.25	37.34	3.51	M	8	0.44	12	0.655	3.42
				F	10	0.56	15		4.27
10a	1.00	47.12	2.16	M	53	0.50	92	0.576	42.59
				F	53	0.50	92		42.59
10b	1.00	47.12	2.16	M	23	0.29	53	0.434	24.54
				F	56	0.71	129		59.72

*Minimum Number Alive

rankings of sites were relatively minor. In addition, relationships among site types remain unchanged.

Table 4 gives estimated densities for adults in 1993. Sample sizes were sufficient for estimation by modelling techniques for 12 of 20 total sites. As for 1992 juveniles, we combined sexes to compute population size estimates, and sex-specific estimates are based on the sex ratio of captured ground squirrels. Again, models we used to derive estimates were generally those with constant survival rates and time-varying capture rates. Despite using previously established (Van Horne et al. 1992) procedures for calculation of area sampled, we believe that these estimates for 1993 are somewhat suspect. Particularly, estimated strip width for shrub sites (15 m) seems much too small, and it does not seem reasonable that strip widths for supplemental feeding sites (7a and 8a) should be smaller (34.5 m vs. 51.9 m) than for unsupplemented sites. However, at this time we do

Table 4. Density estimates of adult Townsend's ground squirrels for site in the Snake River Birds of Prey Area, 1993, at emergence from hibernation. Estimates were obtained directly from modeling techniques except on sites 1a, 1b, 2a, 2b, 3a, 3b, 6a, and 7b where they were computed from pooled estimates of proportion captured (see text for more complete explanation of estimation methods).

Site	Grid Area (ha)	Strip Width (m)	Adjusted Area (ha)	Sex	MNA[a]	Proportion of Total	Estimated Population Size	Proportion Caught	Density (#/ha)
1a	4.50	15.00	5.18	M	4	0.67	6	0.673	1.15
				F	2	0.33	3		0.57
1b	4.50	15.00	5.18	M	1	1.00	1	0.673	0.29
				F	0	0.00	0		0.00
2a	4.50	15.00	5.18	M	2	1.00	3	0.673	0.57
				F	0	0.00	0		0.00
2b	4.50	15.00	5.18	M	2	0.50	3	0.673	0.57
				F	2	0.50	3		0.57
3a	4.50	15.00	5.18	M	1	1.00	1	0.673	0.29
				F	0	0.00	0		0.00
3b	4.50	15.00	5.18	M	5	0.56	7	0.673	1.44
				F	4	0.44	6		1.15
4a	4.50	51.94	6.88	M	13	0.56	18	0.719	2.63
				F	10	0.44	14		2.02
4b	4.50	51.94	6.88	M	14	0.67	29	0.477	4.27
				F	7	0.33	15		2.13
5a	4.50	15.00	5.18	M	19	0.70	30	0.628	5.84
				F	8	0.30	13		2.46
5b	4.50	15.00	5.18	M	27	0.46	42	0.641	8.13
				F	32	0.54	50		9.64
6a	4.50	51.94	6.88	M	2	1.00	4	0.552	0.70
				F	0	0.00	0		0.00
6b	4.50	51.94	6.88	M	12	0.54	23	0.512	3.41
				F	10	0.46	20		2.84
7a	4.50	34.50	6.07	M	32	0.42	70	0.456	11.57
				F	45	0.58	99		16.27
7b	4.50	51.94	6.88	M	8	0.67	14	0.552	2.11
				F	4	0.33	7		1.05
8a	4.50	34.50	6.07	M	50	0.42	83	0.604	13.64
				F	69	0.58	114		18.82
8b	4.50	51.94	6.88	M	19	0.56	35	0.548	5.04
				F	15	0.44	27		3.98
9a	4.50	15.00	5.18	M	16	0.55	23	0.690	4.48
				F	13	0.45	19		3.64
9b	4.50	15.00	5.18	M	27	0.55	37	0.731	7.13
				F	22	0.45	30		5.81
10a	4.50	51.94	6.88	M	21	0.57	49	0.430	7.10
				F	16	0.43	37		5.41
10b	4.50	51.94	6.88	M	20	0.48	30	0.667	4.36
				F	22	0.52	33		4.80

[a]Minimum Number Alive

not have a better estimator for area sampled, so densities were calculated using these questionable results.

Although we have not yet conducted statistical tests, it appears that adult densities are lowest on native shrub sites outside the OTA. Burns both inside and outside the OTA have the next highest adult densities, and sagebrush sites inside the OTA have the highest unmanipulated adult densities (Fig. 5). This contrasts with 1991 and 1992, when burned sites (except for 6a) had the highest adult densities. Adult densities on supplemented sites were about 3 times those on their control sites. Tracking by armored vehicles had no apparent effect on density (Fig. 5).

Offspring Production

For all but 4 study sites, numbers of juveniles captured in 1993 were too low to even attempt estimation by modelling techniques (see Table 5). The total number captured was 249, as compared to 743 the previous year. Although we did construct several models for the 4 sites with reasonable sample sizes, the results were highly inconsistent and thus are not reported here. We believe that it will be necessary to pool data across sites to produce more realistic estimates. This is technically feasible with modifications of existing software, but the procedures are somewhat complicated and could not be completed in time for this report.

Because we trapped the same area on each site, juvenile MNA estimates should give some indication of the relative ranking of site types with regard to juvenile production. Highest numbers were found on the supplemental food sites (Fig. 6). There was very little production on the sage sites except for 1 of the sites that was tracked, as compared to the burn sites (Fig. 6). Production on all but the supplemental food sites was low relative to 1991 and 1992 (Van Horne et al. 1991, 1992).

Numbers of offspring per female did not increase in response to the addition of food (Table 6). Numbers were highest on sites 3b, 5a, and 4b (mosaic, sage, and OTA burn; Table 6).

Chronology of Annual Activity and Reproduction

Adult Emergence.—We used data from 14 sites to evaluate whether there were sexual differences in the timing of emergence in 1993. Data were too sparse on 6 other sites (1b, 2a, 2b, 3a, 3b, 6a). The

Table 5. Number of juvenile Townsend's ground squirrels captured, by sex and overall, on sites in the Snake River Birds of Prey Area, 1993.

Site	Number Captured			
	Female	Male	Sex Unknown	Total
1a	0	0	0	0
1b	0	0	0	0
2a	0	0	0	0
2b	0	0	0	0
3a	0	0	0	0
3b	0	2	0	2
4a	3	6	0	9
4b	16	6	1	23
5a	1	2	0	3
5b	4	3	0	7
6a	0	0	0	0
6b	1	2	0	3
7a	29	36	0	65
7b	1	1	0	2
8a	43	42	0	85
8b	5	8	0	13
9a	2	1	0	3
9b	19	12	0	31
10a	3	11	0	14
10b	17	19	0	36

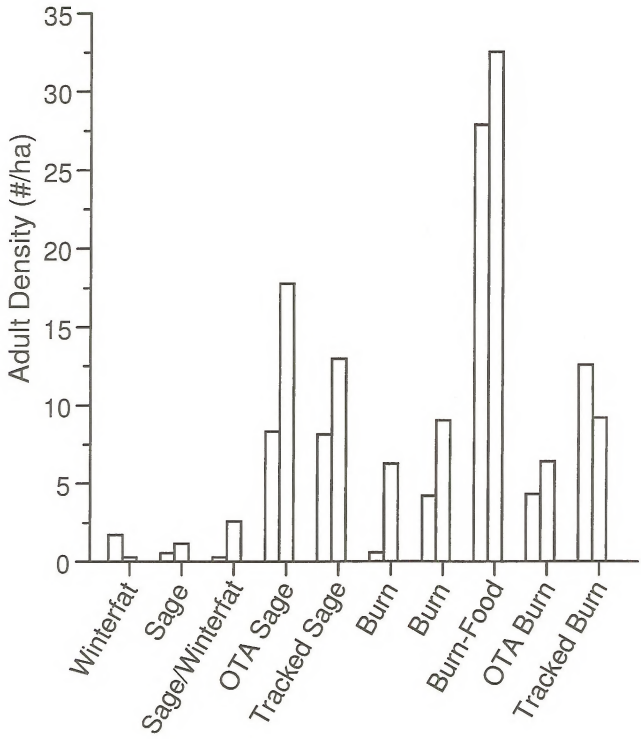

Fig. 5. Adult Townsend's ground squirrel densities for each of the 20 study sites, grouped by habitat type with site pairs clustered.

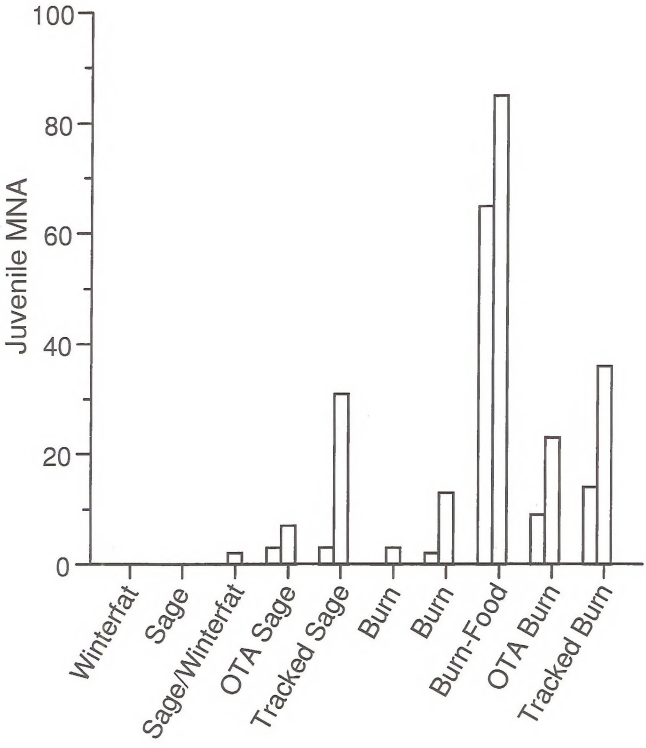

Fig. 6. Juvenile Townsend's ground squirrel densities for each of the 20 study sites, grouped by habitat type with site pairs clustered.

Table 6. Index of reproduction for Townsend's ground squirrels in the Snake River Birds of Prey Area calculated for 1992 as the quotient of juvenile densities prior to 1 May and adult densities prior to the first juvenile capture on each site, and for 1993 as the quotient of the Minimum Number of Alive (MNA) of juveniles captured prior to 1 May and the MNA of adults captured prior to 1 April.

Site		1992 Reproductive Index	1993 Reproductive Index
Winterfat	1a	1.1	0.0
	1b	0.0	0.0
Sagebrush	2a	0.0	0.0
	2b	1.2	0.0
Sage/Winterfat	3a	0.0	0.0
	3b	1.6	2.0
OTA Burn	4a	0.1	0.2
	4b	0.1	1.6
OTA Sagebrush	5a	0.7	1.7
	5b	1.3	0.1
Burned Winterfat	6a	0.0	0.0
	6b	0.4	0.0
Burn, + Food	7a	1.2	1.0
	8a	2.0	0.4
Burn	7b	1.2	0.3
	8b	0.3	0.7
OTA Sage	9a	0.8	0.2
	9b	1.3	0.8
Burn, + Tracked	10a	0.3	0.8
	10b	0.4	0.4

date of first capture was about 2 weeks earlier for adult males (median = 7 February, range = 27 January-21 February, n = 14) than for adult females (median = 22 February, range = 13 February-7 March, n =14). Of the 77 individuals captured from 27 January to 20 February, 69 (90%) were males and 7 (10%) were females. Therefore, sex-specific timing of emergence evidently occurs in Townsend's ground squirrels in some years.

Adult females emerged later in 1993 compared with 1992 (Table 7). The mean difference between years was 12.8 days (SE = 1.59, n = 14). The later emergence probably was caused by prolonged low temperatures and snow cover in 1993.

Reproduction and Juvenile Emergence.— Most males (92.8%, n = 69) captured during the initial trapping occasions (30 January-14 February) had descended testes. These results are consistent with those from 1992 (Van Horne et al. 1992), and they indicate that males likely become scrotal during hibernation or immediately after emergence. Most males remained scrotal until early or mid March, and a few individuals were still scrotal in April (maximum = 21 April). In contrast, males were generally scrotal only through February in 1992, with a maximum date of 17 March (Van Horne et al. 1992). The extended reproductive period for males in 1993 may be related to the late emergence of females, which may have extended the mating period. All 102 adult males captured at least 3 times during the 1993 season had descended testes at ≥1 capture.

Based on the dates of first captures of lactating females, production of litters was later in 1993 than in 1992 (Table 7). In fact, the range of dates did not overlap for the 2 years (Table 7). The mean difference between years was 16.7 days (SE = 2.21, n = 12). Similarly, the first date on which a juvenile was captured was an average of 17.9 days (SE = 2.49, n = 11) later in 1993 than in 1992 (Table 7). Therefore, the general chronology of reproductive events was shifted several weeks later in 1993 compared to 1992. This shift probably was related to temperature and precipitation patterns, and it may have influenced raptor reproductive timing and nestling diets.

On most sites all the adult females captured at least 3 times between 20 February, when we observed the first pregnant female, and 2 June 1993 showed evidence of reproductive activity (pregnant or enlarged nipples) at least once, except on sites 6b, 8a, and 8b (Table 8).

Table 7. Dates of first capture of an adult female, lactating female, and juvenile Townsend's ground squirrels, 1992-93. The median and ranges are for multiple study sites (n). Capture success was too low on some sites to determine dates.

Variable	Year	*n*	Median	Range
Adult Female	1992	14	11 Feb	6 Feb-13 Feb
	1993	14	22 Feb	13 Feb- 7 Mar
Lactating Female	1992	12	7 Mar	1 Mar-16 Mar
	1993	12	23 Mar	18 Mar- 5 Apr
Juvenile	1992	11	29 Mar	22 Mar-20 Apr
	1993	11	14 Apr	5 Apr-26 Apr

Table 8. Percent of female Townsend's ground squirrels in the Snake River Birds of Prey Area captured at least twice (1991) or 3 times (1992, 1993) that showed evidence of having entered reproductive condition, based on pregnancy or enlarged nipples.

Site		1991 % Reproductive (n)	1992 % Reproductive (n)	1993 % Reproductive (n)
Winterfat	1a	75 (4)	100 (3)	—
	1b	100 (2)	100 (4)	
Sagebrush	2a	100 (1)	—	—
	2b	—	—	—
Sage/Winterfat	3a	—	100 (1)	—
	3b	—	100 (4)	—
OTA Burn	4a	100 (7)	96.7 (30)	100 (2)
	4b	100 (9)	92.3 (26)	100 (3)
OTA Sagebrush	5a	100 (5)	100 (18)	100 (1)
	5b	100 (12)	60 (20)	100 (12)
Burned Winterfat	6a	—	—	—
	6b	100 (6)	100 (26)	33.3 (3)
Burn, + Food	7a	100 (19)	100 (18)	100 (13)
	8a	100 (9)	100 (19)	94.9(34)
Burn	7b	75 (4)	100 (12)	100 (1)
	8b	100 (10)	100 (21)	83.3 (6)
OTA Sage	9a	100 (6)	100 (14)	100 (4)
	9b	100 (8)	88.9 (18)	100 (9)
Burn, + Tracked	10a	100 (13)	100 (37)	100 (3)
	10b	100 (20)	100 (32)	100 (5)

Adult and Juvenile Immergence.—In 1992, the last capture of adult females was later than the last capture of adult males on 15 of 16 sites (Van Horne et al. 1992). In 1993, trends were less clear for timing of immergence between the sexes. Males were last captured on a later date than females on 6 sites, females were captured last on 3 sites, and both sexes were last captured on the same day on 5 sites. The data from 1993 should be interpreted with caution, however, because the overall number of captured squirrels was small on most sites. Nevertheless, these results suggest that inter-sexual differences in immergence of adult Townsend's ground squirrels may vary among years, possibly depending on environmental conditions. In general, immergence of adult and juvenile squirrels began in May in 1993, with the last capture of individuals occurring in late May to mid-June.

Tag Loss

Within-year.—We detected 8 PIT tag losses in 1992 and 2 tag losses in 1993 (Table 9). Estimates of tag loss depend on the loss rate of dye (Table 9). The average probability of dye loss on any occasion was 0.039 (n = 70, SE = 0.009). This rate was similar to the intra-cycle rates of dye loss that we reported for 1991 (Schooley et al. 1993) from similar time intervals (ca. 1 week). In addition, most (80%) of the reported dye loss was between 16 April and 5 May, and most dye losses

Table 9. Estimates of within-year tag loss (T) for passive integrated transponders (PIT) implanted in Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992-93. Tag loss rates are presented for 5 loss rates of dye (0 - 0.5), which was used as a second independent mark.

Year	Age and Sex[a]	Individuals Recaptured with Functional PIT (n)	Individuals Recaptured without Functional PIT (n)	PIT loss rate[b] (T) 0	0.05	0.1	0.25	0.5
1992	Adult Male	66	1	0.0150	0.0157	0.0166	0.0199	0.0295
	Adult Female	64	1	0.0154	0.0162	0.0170	0.0204	0.0303
	Juvenile Male	66	2	0.0294	0.0309	0.0326	0.0388	0.0571
	Juvenile Female	99	4	0.0388	0.0408	0.0430	0.0511	0.0748
1993	All classes[c]	50	2	0.0385	0.0404	0.0426	0.0506	0.0741

[a]Adults were ≥1 year old, and juveniles were young-of-year.
[b]Probability of tag loss (T) = X/(1 + X - L), where X = (number of individuals recaptured without functional PIT)/(number of individuals recaptured with functional PIT), and L = probability of dye loss.
[c]18 adult males, 10 adult females, 8 juvenile males, and 14 juvenile females.

(>90%) were from adults. These dye losses probably had little effect on our estimates of tag loss, because we tagged most adults much earlier in the year and most or all the tag loss occurs near the time of tagging.

Therefore, we assumed an average dye loss rate of 0.05. The resulting PIT loss rate was 0.0259 for the 4 sex-age classes in 1992 (Table 9), with a corresponding 95% CI of [0.0125, 0.0537]. This estimate was similar to our reported 1991 estimate ($\bar{x}$ = 0.0343, 95% CI = 0.0159, 0.0739). The estimate of tag loss for the combined sex-age classes in 1993 (0.0404, Table 9) was also consistent with estimates for other years. In summary, data for 1992 and 1993 support our conclusion (Schooley et al. 1993) that tag losses within a year were probably <0.05.

Between-year.—We captured 60 individuals in 1993 with dye marks retained from 1992. Twenty-seven of these 60 squirrels were tagged in 1992, and all of these animals had working PIT tags (Table 10). An additional 33 squirrels, which were PIT tagged in 1991, were captured in 1993 with dye marks from 1992. All of these animals also had PIT tags (Table 10). These data provide an estimate of the probability of losing a PIT tag between 1992 and 1993 given that the PIT was retained from 1991 to 1992. In summary, we have not yet detected any PIT tag loss between years.

Hole Counts

Densities of TOTAL holes were greater on burn sites ($\bar{x}$ = 229/ha, range: 117 - 464/ha) than on shrub sites ($\bar{x}$ = 123/ha, range: 65-238/ha). The proportion of TOTAL holes classified as ACTIVE was variable among sites (range: 0.19 - 0.60) and averaged 0.38 (n = 20). Observers classified less than half the holes with high certainty ($\bar{x}$ = 0.45, SD = 0.04). The number of TOTAL holes per

Table 10. Estimates of rates of PIT-tag loss between years for Townsend's ground squirrels at the Snake River Birds of Prey Area.

Time interval	Number of animals that retained dye marks between years	Number of tag losses	95% CI for tag loss
1991-92	92	0	[0, 0.027]
1992-93[a]	27	0	[0, 0.069]
1992-93[b]	33	0	[0, 0.057]

[a]Individuals PIT tagged in 1992.
[b]Individuals PIT tagged in 1991.

Table 11. Spearman rank correlations (Rs) of total Townsend's ground squirrel density (adults + juveniles/ha) with 3 measures of hole densities. We conducted hole counts from 8 to 13 June 1993. Results are presented for all sites, and with our 2 supplemental feed sites (7a, 8a) excluded.

	All sites			Supplemental Feed Sites Excluded		
Hole Variable	R_s	*P*	*n*	R_s	*P*	*n*
Total	0.40	0.0768	20	0.33	0.1762	18
Active	0.45	0.0450	20	0.40	0.0985	18
Possibly Active	0.42	0.0660	20	0.36	0.1481	18

ground squirrel also was extremely variable, with an average of 41 (SD = 60.7) on burned sites and 111.8 (SD = 138.4) on shrub sites. These mean values for TOTAL holes per squirrel were substantially higher than the means for 1992 (burn = 10, shrub = 23).

In 1993, squirrel densities were only marginally correlated with TOTAL, ACTIVE, and POSSIBLY ACTIVE holes (Table 11, Fig. 7). There was no relationship between ground squirrel densities and hole densities within the 10 burned sites (TOTAL: $R_s = 0.21$, $P = 0.5563$; ACTIVE: $R_s = 0.28$, $P = 0.4250$) or within the 10 shrub sites (TOTAL: $R_s = 0.30$, $P = 0.3932$; ACTIVE: $R_s = 0.24$, $P = 0.5096$). Associations between holes and squirrels were weaker for 1993 than for 1992 (Fig. 7). In addition, TOTAL holes were a better predictor of squirrel densities than ACTIVE holes in 1992, whereas ACTIVE holes were a slightly better predictor in 1993 (Fig. 7).

We also examined the association between holes and squirrels in 1993 with data from our 2 supplemental feed sites (7a, 8a) excluded. We thought that this treatment could confound correlations, because animal movements (residency vs. transiency) might differ from untreated sites. With the supplemental sites excluded, squirrel densities were not correlated with TOTAL or POSSIBLY ACTIVE holes, and they were only weakly correlated with ACTIVE holes (Table 11). Clearly, the extremely high densities of holes (TOTAL = 464) and squirrels (51) on supplemental site 8a increased the overall correlation (Fig. 7).

A reasonable index of squirrel density should, at a minimum, detect major increases or decreases in squirrel populations between years. Our estimates indicate that the densities of squirrels were much lower in 1993 than in 1992 (Table 12). The densities of TOTAL and ACTIVE holes also were less in 1993 than 1992 (Table 12). Hole counts did not, however, indicate the degree of the decline in squirrel densities. The decline in mean squirrel densities between years was 69% on burned sites and 54% on shrub sites. The decline in mean densities of TOTAL holes was only 40% on burned sites, and 21% on shrub sites. Similarly, the decline in mean densities of ACTIVE holes was only 33% on burned sites and 37% on shrub sites. Therefore, although the hole counts indicated the correct direction of the population trend, they were insensitive to the magnitude of the decline.

Table 12. Densities (number/ha) of Townsend's ground squirrels (adults + juveniles), TOTAL holes, and ACTIVE holes, 1992-93. All means are for 10 sites.

		1992		1993	
Variable	Habitat	$\bar{x}$	SE	$\bar{x}$	SE
Squirrels	Burned	54.4	7.49	16.8	5.28
	Shrub	13.9	3.90	6.4	2.43
TOTAL Holes	Burned	381.4	29.0	228.9	34.2
	Shrub	155.6	19.9	122.5	17.6
ACTIVE Holes	Burned	159.0	24.4	107.9	21.8
	Shrub	63.5	10.4	39.9	6.39

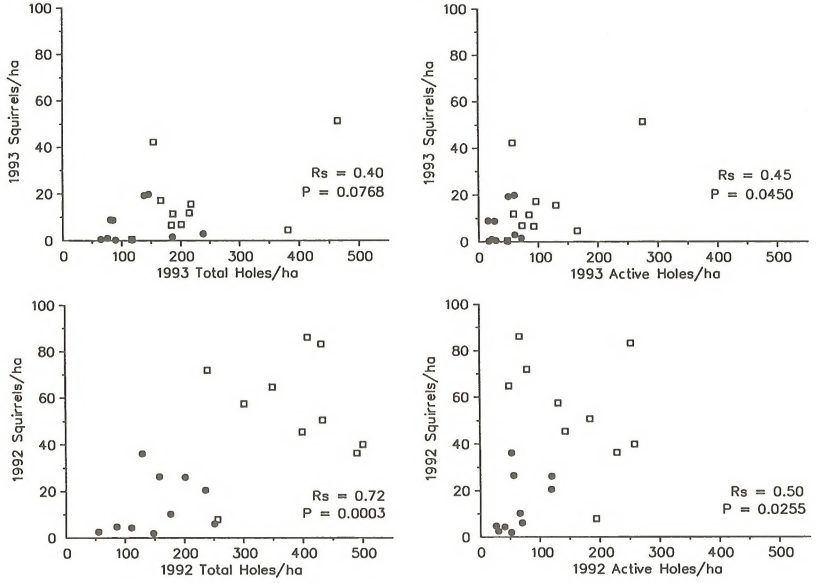

Fig. 7. Densities of Townsend's ground squirrels compared with total and active holes, 1992 and 1993. Open squares indicate burned sites, and closed circles indicate shrubby sites.

Hole Phenology

Of the holes classified as active in June 1992, the proportion that was classified as active in May 1993 ranged from 0.18 to 0.60 among sites (Table 13). These proportions differed among habitats, with the highest proportion of holes classified as active in sage habitat ($\bar{x}$ = 0.59, SD = 0.01), followed by burned sage ($\bar{x}$ = 0.36, SD = 0.03), and then winterfat ($\bar{x}$ = 0.21, SD = 0.04). Furthermore, the persistence of holes may be habitat-specific (Table 13), with holes surviving at a lower rate on burned habitats than on shrub-dominated habitats. This trend should be interpreted with caution, however, because the lowest persistence was on Site 7a, which was 1 of 2 sites supplied with food in 1993. We expected that increased densities associated with supplementation would have increased hole persistence. Overall, the observer (R. L. Schooley) classified 57% of the 156 inactive holes with high certainty, and 59% of the 116 active holes with high certainty.

The comparison of results for Site 7b between the mid-March survey and the early May survey (Table 13) suggests that substantial temporal changes in classification of holes can occur within a year. The proportion of active holes decreased from 0.64 to 0.38 between surveys. We also examined this trend by examining individual holes to determine the degree of agreement in classification (absent, inactive, active) between surveys. Only 48% of the 50 holes were classified the same in both surveys. Seventeen (65%) of the 26 cases of disagreement were due to holes classified as active in March but inactive in May. This within-year decrease may be explained, in part, by the low density of squirrels on Site 7b in 1993 (4.2 adults/ha estimated density and 0.4 juveniles/ha MNA).

Persistence through the Torpid Period

The percentage of animals recaptured following the 1992-93 torpid period was much lower than the percentage following the 1991-92 torpid period (Fig. 8). Adult female persistence was reduced more than adult male persistence, and only 9 of 1,423 animals marked as juveniles in 1992 were recovered in 1993. Persistence was reduced more on burned sites than on native shrub sites (Fig. 9). Two factors may have played a role: (1) there were few alternative foods to *P. secunda* on the burned sites while native shrubs on the shrub sites did not completely dry out, and (2) the native shrubs shaded some of the *P. secunda*, so that it may have stayed green longer on shrub sites.

Sex Ratio

Reduced female persistence was associated with a reduction in the mean adult sex ratio to 45.2% female for 14 sites with 4 or more adults captured, as compared to 66.0% in 1991 and 58.7% in 1992. The positive relationship between adult density and female skew remained significant (R^2 = 0.502, df = 13, P = 0.0046; Fig. 10).

Table 13. Proportion of holes of Townsend's ground squirrels classified as absent, inactive, or active by a single observer on 5-10 May, 1993. All holes on each site (n = 50) were classified as probably active in mid-June, 1992.

Site	Hole Absent	Hole Present	
		Inactive	Active
Winterfat (1a)	0.02	0.80	0.18
Winterfat (1b)	0.10	0.66	0.24
Sage (2a)	0.04	0.38	0.58
Sage (2b)	0.02	0.38	0.60
Burned Sage (7a)	0.28	0.38	0.34
Burned Sage (7b)	0.10	0.52	0.38
Burned Sage (7b)*	0.14	0.22	0.64

*Surveyed on 13 March 1993 by same observer.

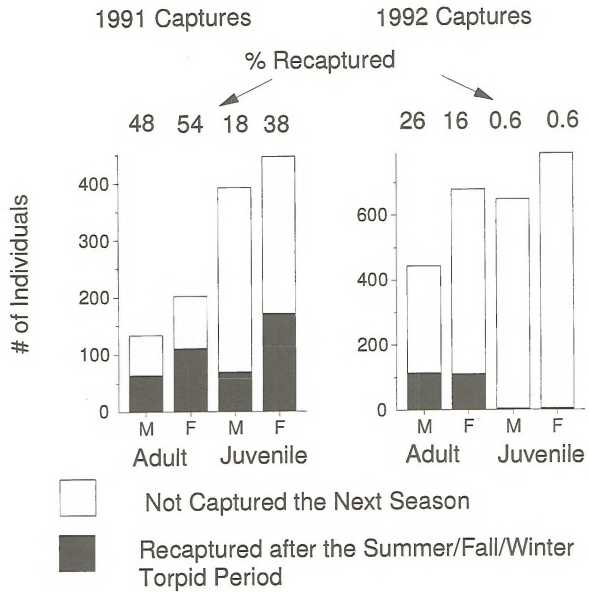

Fig. 8. Numbers of Townsend's ground squirrels of each age and sex class trapped in 1991 and 1992 (total bars), and numbers recaptured after the following torpid season (solid bars). Percent recaptured is indicated at the top of each bar.

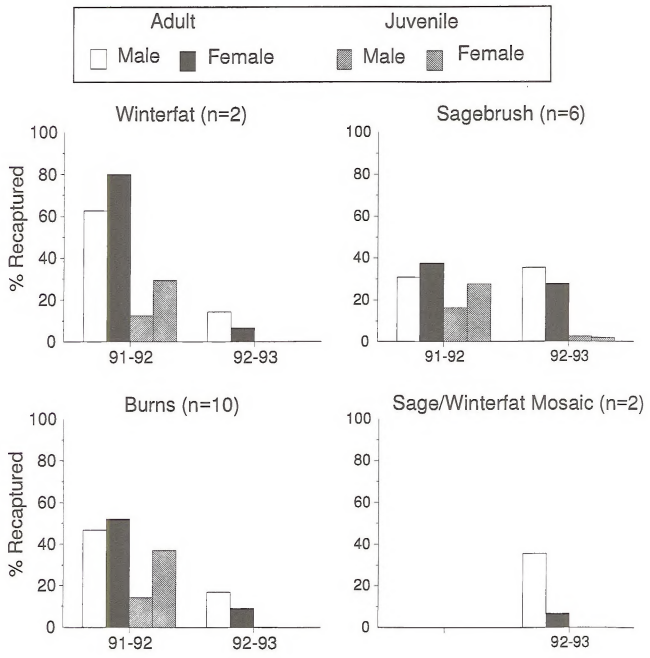

Fig. 9. Percent of Townsend's ground squirrels in each age and sex class present each year that were recaptured following the torpid season, averaged for sites within habitat types.

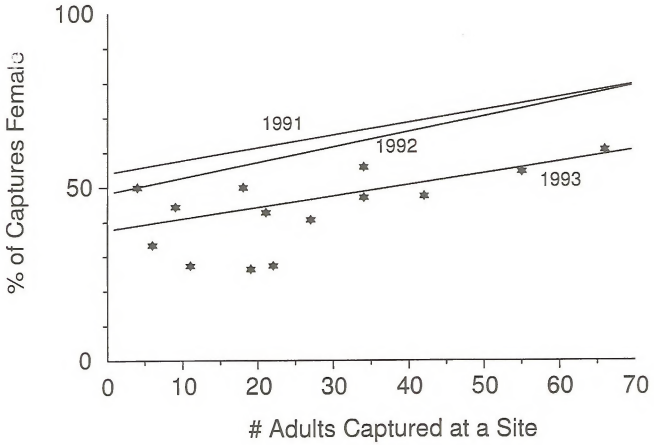

Fig. 10. The relationship between the mean percent of the adult population Townsend's ground squirrels on each site that was female and total density on that site for each of the 3 years (lines). Point scatter is indicated for 1993.

PLANS FOR NEXT YEAR

We expect that the low densities and low production in 1993 will result in even lower densities in 1994. The effect of these factors will be further magnified by the nearly complete loss of the 1992 juvenile cohort, so that almost all animals that remain will be either at least 3-yr old or yearlings. We will continue the livetrapping on all sites, as well as the food supplementation. Although we will continue to monitor marked holes, we will not repeat the hole counts.

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Appendix A. The death-only Jolly-Seber model.

The Jolly-Seber (JS) model is the standard starting place for estimation of survival rates and population size for capture-recapture data (Pollock et al. 1990, Lebreton et al. 1992). Let k denote the number of capture occasions; then the parameters in the JS model are N_1, B_1, ..., B_k, and the φ_1, ..., φ_{k-1}, p_1, ... p_k; N_i is the population size at capture occasion 1. Subsequent recruitment in time intervals i to i + 1 is B_i. Survival rates between intervals are φ_i; and capture probability at occasion i is p_i (this notation is standard; further explanations are in cited references). Detailed derivations and theory for the JS model are in (among other places) Burnham (1991).

The death-only (or no recruitment) model assumes $B_1 = B_2 = \cdots = B_{k-1} = 0$, thus the only abundance parameter is N_1. This model is reasonable for adults from emergence until at least recruitment of young. It is also a reasonable model for captures of young of the year until they start dispersing. The statistical model for the data under death-only JS is known; the representation we used is

$$
\begin{aligned}
u_1^* &\sim bin(N_1, (p_1 + q_1\lambda_1)), \\
u_i \mid u_1^* &\sim bin(u_1^*, \tau_i), \\
r_i \mid R_i &\sim bin(R_i, \lambda_i) \qquad , i = 1, \ldots, k-1 \\
r_i \mid (T_i + u_i^*) &\sim bin((T_i + u_i^*), \tau_i) \qquad , i = 2, \ldots, k-1.
\end{aligned}
$$

These summary statistics (u_1^*, u_i, R_i, etc.) will not be defined here. Rather, our point is that the statistical model becomes a product of conditionally independent binomial distributions ("bin"); it is straightforward to fit data to such binomial distributions in PROC NLIN of SAS. Moreover, special cases of the death-only JS model correspond to restrictions on the survival and capture parameters. PROC NLIN provides a convenient way to impose such restrictions hence fit the data to such models, using maximum likelihood estimation (hence all this data analysis was done in the likelihood framework, and generalized model fitting spirit, of Lebreton et al. 1992).

The types of restricted models considered are, for example, to have constant per day survival rates:

$$\varphi_i = \varphi^{t_{i+1} - t_i} \equiv \varphi^{\Delta_i} \equiv e^{\log(\varphi)\Delta_i} \equiv e^{\alpha\Delta_i}.$$

Here the t_i are the days on which trapping is done. Models may also have per-day survival rates constant over periods of time, or be generalized to allow smoothly varying per-day survival rates with forms like

$$\varphi_i = e^{\alpha\Delta_i + \beta(t_i - \bar{t})^2}.$$

Restricted models on the capture probabilities are easier to construct, for example $p_i = p$, for all i. In general, we use a logit-link for models on the capture probabilities (as above the survival rate models are based on a log-link: models of $\log(\varphi_i)$ being linear):

$$\log\left[\frac{p_i}{1 - p_i}\right] = \gamma + \tau(t_{i+1} - t_i) + \Theta(t_{i+1} - t_i)^2,$$

or

$$\log\left[\frac{p_i}{1 - p_i}\right] = \gamma + \tau i + \Theta(i)^2,$$

Such models are in the generalized linear modeling framework of Lebreton et al. (1992). Information theoretic model selection (eg., Akaike 1985) was done, or tried, as per Burnham and Anderson (1992), Lebreton et al. (1992) and Anderson et al. (in review).

Some Processes Influencing Reproduction and Survival of Townsend's Ground Squirrels

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ANNUAL SUMMARY

Mean masses of adults lagged those in previous years early in the season, but reached higher levels at the end of the season than during 1992. Food supplementation increased neither mean masses nor percent fat. Animals that persisted through the torpid period were likely to be heavier in weight and to have been trapped later in the 1992 season than animals that did not. Animals captured inside grazing exclosures did not differ in body mass from those outside. Tracking had little effect on the vegetation, and produced no apparent differences in ground squirrel body mass or reproductive rates. ***Poa secunda****, a native bunchgrass that is a common food item, remained succulent later in the season in 1993 than in 1992. Differences in diet among habitats in 1992 were similar to the patterns in 1991. In cafeteria tests, animals consumed the greatest wet weight of* ***P. secunda****, and the greatest dry weight of winterfat,* ***Ceratoides lanata****, when these were offered along with big sagebrush,* ***Artemisia tridentata****.*

OBJECTIVES

The overall objective is to investigate experimentally the processes behind observed patterns of survival and reproduction across habitats. These processes can best be listed as questions that represent hypotheses:

1. How do body mass and body condition (% fat) vary with habitat? How do these attributes influence survival through the torpid period, ability to avoid predators, and reproduction?

2. What is the role of vegetation (percent cover and phenology) in determining diet? Are different diets associated with different patterns of mass gain?

3. What are the preference rankings among the 3 main food items? Do animals from sage or winterfat-dominated sites have a relatively greater preference for these shrub species than do animals from burned sites?

4. What is the role of fats in determining food preference, body condition, and survival through the torpid period?

5. Does genetic information indicate high levels of dispersal and interfertilization among populations, or are populations in different habitats relatively isolated? (Although this objective will not be addressed under the current study, we are collecting and storing the material while we have the opportunity, so that we can answer the question in a future study).

METHODS

Body Mass and Body Condition

Live Animals in the Field.—For general trapping methods, see Van Horne et al., (this volume). We weighed each animal captured during livetrapping with a spring scale. Only masses from the first capture of an individual within a day were used in calculations. We assessed overwinter persistence of ground squirrels through the 1992-93 winter in the same manner as described previously (Van Horne et al. 1992).

One of us (J. C. Corn) measured the mass and body composition of male ground squirrels with a total body electrical conductivity analyzer (TOBEC model SA-2; see Corn and Van Horne 1991) at emergence from hibernation to determine their condition early in the active season. Study 4 technicians captured animals and assessed their body composition during regular livetrapping at 7 sites (1a, 4a and b, 5a and b, and 8a and b) from 2 to 14 February. These sites are the same as those sampled in 1992 except that we did not assess animals on site 1b, as densities were too low. Sites 8a and b were visited twice each; all other sites were sampled once each. Data from sites 8a and b served as a baseline against which the effects of supplemental feeding on site 8a could be measured.

J. C. Corn measured mass and body composition of ground squirrels prior to estivation on 6 sites (4a and b, 5a and b, and 8a and b) in May. She visited all sites twice except 8a, which was visited once. We did not trap sites 1a and b during the period when the TOBEC was in the field (12 to 25 May) because of low capture rates.

Maximum Running Speed.—We conducted this research on a burned area dominated by grasses and forbs that is not 1 of our 20 demography sites. We livetrapped squirrels by placing several traps near holes that seemed to be active squirrel burrows (ca. 45-90 traps for 2 sessions). Only adult males were retained for trials because we were concerned that body mass of females could be confounded by their reproductive status and history. We marked adult males with black dye for within-season identification, and recorded relevant capture information (body mass, reproductive condition, capture status). Individuals were kept in covered cages, in the shade, prior to time trials. We conducted all time trials on the same running track, a compact dirt substrate (1 track of a 2-track road) about 0.7 m wide. To force squirrels to run on the track, we erected particle boards (ca. 0.6 m high) on both sides along the length of the track. We marked 3 distances on the track with florescent orange paint: start (0 m), middle (5 m), and finish (10 m). Incline can influence Maximum Running Speed (MRS) of sciurids (Blumstein 1992). Although our track was relatively flat, we ran all individuals in the same direction to remove potential effects of incline. All trials were run on a dry substrate with calm winds (<8 km/hr).

For a trial, we released an animal from its trap, and 1 person chased it down the track by running behind it, yelling loudly, and beating the ground with a sage branch. The same person was used as the "chaser" for all trials. Other researchers (Trombulak 1989, Blumstein 1992) have used similar methods to encourage other sciurids to run at maximum speeds. To avoid timing squirrels before they had responded to the chaser, we released the animals 1.5 m before the start line. Two people recorded running times within 0.01 sec with hand-held stopwatches that were synchronized prior to each trial. One person recorded the start time and the 5-m split time; the other person recorded the 10-m finish time. The same 2 people always recorded the same times. The end of the track was not blocked, so squirrels continued to run past the finish line (i.e., they were not decelerating at the finish). We noted whether squirrels seemed to be running at full speed. If they hesitated substantially during the run, or if they ran in a non-linear path, we recorded their times but coded them as being less than maximum speeds, and did not include these data in statistical analyses.

It was necessary to sample individuals over time to obtain a sufficient range of body masses to test our hypotheses, because body masses do not vary enough among individuals at a specific time. Therefore, our general design was to attempt to recapture individuals throughout the season and obtain repeated measurements of MRS at different body masses. We also used a within-subject design to test for effects of distance, because we could calculate MRS for both the 0-5 m split and the 5-10 m split. We thought this design would be more efficient than a between-subjects design, such as randomly assigning squirrels to a range of distances (Blumstein 1992).

Exclosures.—During 8-12 February, we trapped animals inside grazing exclosures to see whether they had a higher body mass than controls trapped outside the exclosures. We used 2 sage-dominated exclosures, 1 winterfat-dominated exclosure, and 1 burn exclosure. The sage-dominated exclosures each covered 64.75 ha (1/4 section), and the others were 16.19 ha (1/16 section). All have excluded grazing by large herbivores for approximately 12 years, except the burn exclosure, which showed evidence of use by cows within the past year. Approximately 20 traps were set in a crossed pattern at the center of each exclosure with 15 m spacing between traps. Traps were checked every 1.5 hrs and captured animals were weighed with a spring scale, dyed, and released. No data were taken from dyed animals captured subsequently.

Growth Rates of Captive Litters.— Two captive Townsend's ground squirrels captured in the Snake River Birds of Prey Area (SRBOPA) on a burn near our site 7b, gave birth to litters on either 9 March (pm) or 10 March (am) 1993. We have assumed 10 March was the date of birth for the following data summaries. Female A produced 8 young, and Female B produced 6 young. Females were housed with their litters in an individual cage (2 cages, 2 family units). We provided rat chow and water *ad libitum*, and we supplemented these with apples and green vegetation (primarily Kentucky bluegrass, *Poa* sp.). On 4 occasions (17, 21, and 28 March; 8 April), we weighed all individuals (mothers and young) and recorded some basic developmental information for the young. We did not determine sexes of the young. We released the family units in the SRBOPA. All young survived until they were released.

Vegetation

General.—We sampled vegetation (Van Horne et al. 1991) on all sites during 3 different periods: 7 - 10 March, 12 - 15 April, and 22 - 24 May. These corresponded with 3 periods in which we collected fecal samples for dietary analysis: 13 February - 13 March, 10 April - 5 May (mostly mid-April), and 17 - 31 May. Some plant phenology information comes from this data set, as we classified plants as either succulent or desiccated.

Experimental Tracking.—We examined characteristics of shrubs on the 4 sage sites inside the OTA for 2 years prior to experimental tracking (1991 and 1992) and for 1 year after tracking (1993). We were interested in whether we could detect any short-term changes in vegetation caused by our tracking treatments. Our scale of comparison was at the site level, and thus we had 2 controls (5a, 5b) and 2 treatments (9a, 9b). We examined treatment effects for 2 variables (shrub density and shrub height) by comparing the differences between control-treatment pairs (5a - 9a, 5b - 9b) that were spatially matched (see Van Horne et al., this volume, Fig. 1).

Plant Phenology.—We recorded basic plant phenology data for common species of grasses and forbs on our 20 study sites on every trapping occasion, about once per week. Species were catagorized according to vegetative stages that included (1) early growth, leaves/blades unfolding, (2) mostly to fully developed, generally coinciding with presence of reproductive structures, (3) withering and drying, and (4) desiccation of above-ground growth. We also recorded the date when individuals on a site first reached a certain stage, and when most (>50%) individuals reached that stage.

Diet

Fecal Samples.—We collected 92 fecal samples from adults during the first period, 81 samples from adults and 54 samples from juveniles during the second period, and 35 samples from juveniles during the third period. Fecal samples have not been analyzed, as laboratory processing through the Composition Analysis Lab in Fort Collins, CO takes at least 6 months. Data from the 1992 season will therefore be presented here.

Forage Selection.—During behavioral observations it is relatively simple to determine which species are being chosen for forage, but it is difficult to determine the actual portions of these forage species that ground squirrels are selecting. Therefore, squirrels were collected during 2 periods for analyses of their stomach contents. Squirrels were collected either through shooting or the use of snap traps in OTA burned sagebrush and OTA sagebrush habitats from 2-13 March and 17-22 May 1993, corresponding with fecal collections during the mark-recapture portion of Study 4. We were unable to collect animals from winterfat habitats because of low animal densities. Stomach and fecal samples were collected and dried at 65° C for 24 hours. We will analyze stomach contents for acid detergent fiber

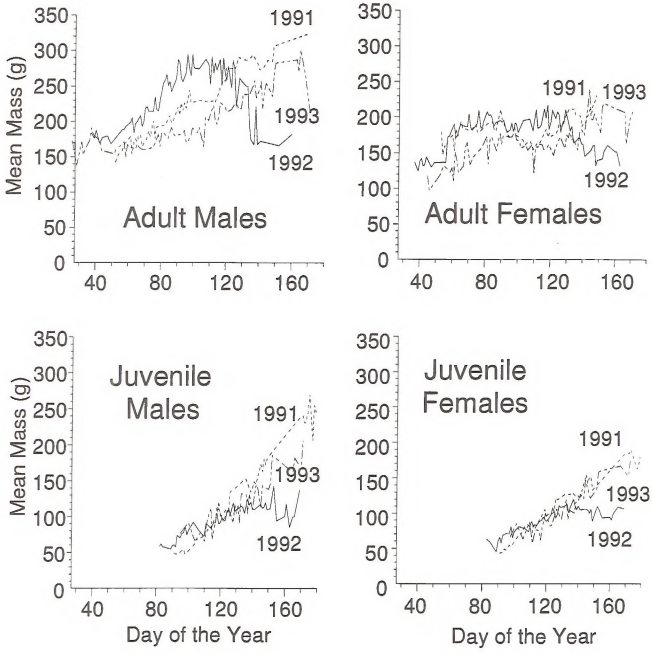

Fig. 1. Body mass averaged across sites for each sex and age class of Townsend's ground squirrels from the Snake River Birds of Prey Area for 3 years.

(ADF), neutral detergent fiber (NDF), lignin, protein, gross energy, and lipid content by the Nutrient Analysis Laboratory at Colorado State University, Ft. Collins, to obtain an estimate of forage quality in different habitats and at different times of the season. When sufficient stomach and fecal samples are available for individuals, we will send samples of both to the Composition Analysis Laboratory at Colorado State University to correct the proportions found in fecal analyses for differences in digestibility.

Fat Deposition Patterns.—J. C. Corn measured seasonal variation in the fatty acid composition of ground squirrels from adipose tissue samples of animals collected in March and May for diet quality and reproduction information (see above). Ground squirrel carcasses were frozen after we removed other tissues and transported to Colorado State University frozen. She removed adipose tissue samples from slightly thawed carcasses and placed them in 0.9% NaCl, then immediately extracted fatty acids and characterized them as described previously (Van Horne et al. 1992).

Fats in the Diet.—Vegetation samples were collected to measure sources of fats in the diets of ground squirrels using the approach described in Van Horne et al. 1992 but with different handling procedures in the field. During laboratory analyses, we found that fats from plant tissue samples collected in 1992 were poorly preserved, possibly due to drought, handling of plant material immediately after collection, and/or storage conditions. We modified our field handling procedures, separating plant parts of each species immediately after collection and freezing them rapidly by immersion in liquid nitrogen. We then transported plants to Colorado State University frozen, and freeze dried them immediately. We divided a few of the plant samples in half, with one-half being freeze dried and the other half held in a freezer, to assess the effect of frozen storage on sample degradation. Sample analysis is scheduled for November.

Role of Fats in Patterns of Torpor in the Laboratory.—Preliminary feeding experiments to manipulate fatty acid composition of adipose tissues of captive Townsend's ground squirrels and test for variation in torpor bout duration revealed a wide variation in torpor bout duration within treatment groups. We estimated sample size requirements to be approximately 15 animals per treatment. We captured animals from a burned sage site at the northwest edge of the OTA, transported them to Colorado State University, weighed them and analyzed them in the TOBEC, and assigned them to 1 of 2 experimental treatments: a high-PUFA (polyunsaturated fatty acid) diet of rat chow pellets soaked in sunflower oil or a low-PUFA diet of chow soaked in hydrogenated coconut oil. Three ground squirrels captured in 1991 from the SRBOPA near Coyote Butte served as controls, and were fed untreated rat chow pellets. We maintained animals on experimental diets for 2 months, and weighed them approximately twice weekly. After 2 months, J. C. Corn ran animals through the TOBEC . She surgically removed subcutaneous adipose tissue samples from approximately half the animals in each experimental group for fatty acid composition analysis. After a 2-week recovery period, torpor was induced by removing food and water. When the ground squirrels became torpid (within 5 days for most animals), we mounted thermocouple wires in their cages, and an automated data logger recorded chamber temperatures. Temperature changes indicate when each ground squirrel arouses and the duration of arousal. Comparisons of torpor bout duration between treatment groups will be made over a range of ambient temperatures.

Cafeteria Tests.—The first of 2 sets of trials began on 9 February 1993 and ended on 14 February 1993. Animals were placed in laboratory cages with apple, water, and rat chow *ad lib* within 3 hrs of capture. Within 6 hrs we removed them to cages where they were offered measured quantities of the trial foods collected the same day from the SRBOPA. Cages were equipped with water and polyester bedding. Control cages contained no animals. Approximately 24 hrs later we either removed the animals from the experiment, or transferred them to freshly prepared experimental cages. We then weighed the food materials remaining from the trial and placed them in a drying oven. No animal was subject to experimental treatment for more than 3 24-hr periods. We took final weights of remaining foods when plant weights reached an asymptote. Data from occasions in which animals consumed <5 g wet weight of the food offered were omitted from the analysis.

We followed essentially the same procedures in the second set of trials, which began on 7 March 1993 and ended on 12 March 1993. We offered

each of these animals only 1 set of food, however, for approximately 12 hr. Occasions in which the animals consumed <2 g dry weight of the food offered were omitted from the analysis.

Genetics

We sampled squirrels from 3 areas: Area 1 (Sites 4a, 4b, 10a, 10b), Area II (Site 6b), and Area III (Sites 5b, 9b). We planned to sample a fourth area (Sites 1a, 1b) but were unable to obtain any material. We collected material either by tail clipping animals on established sites (mostly on assessment lines) or by collecting animals near sites. We also used collected animals to obtain data on litter sizes, internal parasites, stomach ulcers, and fat deposits. When possible, we recorded the animal's age, sex, reproductive status, body mass, and location within the collection area.

For tail clipping live animals, we used canine nail clippers to snip a small section of the tail tip, including just enough of the tail to contain a small piece of bone. We cleaned the distal third of the tail with Providine surgical scrub before and after clipping, and we also applied an antibiotic cream after clipping. We stored samples in a lysis buffer in individually marked tubes. We kept the samples refrigerated until we could store them in freezers (-80 C) at the Biology Department at Colorado State University. We collected off-site animals by shooting or by snap trapping. Carcasses were kept frozen prior to necropsies.

RESULTS AND DISCUSSION

Body Mass and Body Condition

Live Animals.—We used the mean weight of all animals captured on a given day, across sites, to obtain a general pattern of mass dynamics that we could compare with 1991 and 1992 (Fig. 1). Mean mass across sites at the end of the 1993 season was higher than that in 1992 for all sex and age groups, but generally slightly lower than that at the end of the 1991 season. Mean mass of both adult males and adult females was lower than that in previous years for about the first half of the season. This probably resulted from a combination of the prolonged snow cover early in the season (Van Horne et al., this volume) and poor body condition at emergence as a consequence of the 1992 drought (Van Horne et al., this volume).

To investigate habitat effects on body mass more closely, we summarized patterns of mass dynamics by calculating the mean mass within sex and age classes across sites within habitat types for each week during the active season. We include results for 1991 and 1992 for comparison (Figs. 2-4). In 1991 masses on the winterfat sites were relatively low, whereas adult masses on the burns were marginally higher than those on the sage sites, and juvenile masses on the sage sites were higher than those on the burn sites (Fig. 2). In 1992 adult masses on the winterfat sites were relatively low, whereas adult masses on the sage and winterfat sites were similar. Juvenile masses were low on all sites (Fig. 3). In 1993 adult and juvenile female masses were lowest on the food supplemented sites (Fig. 4). No other differences among sites types appear consistent.

We compared body masses at last capture for all animals whose last capture was on or after 1 May in both 1991 and 1992 between those animals that were recaptured the following season and those animals that were not (Table 1). Body masses of recaptured animals tended to be higher in both years. Dates of last capture for recaptured animals were later in 1991 for all animals and in 1992 for juveniles, but adult males recaptured in 1993 immerged earlier than those that were not recaptured in 1993 (Table 2). This indicates that some adult males may have survived through early immergence in drought conditions. Because of reproductive costs, adult females may not have been able to use this strategy.

Few ground squirrels whose body composition was assessed in May 1992, were captured in 1993 (Table 3). Of the 5 survivors, 3 were from sage sites, and 2 were from burned, reseeded sites; adults and juveniles of both sexes survived. We did not recapture any of the ground squirrels from winterfat or burned sage sites. Although sample sizes are too small for statistical comparison, there are no apparent differences in size or body composition between the few survivors and the many whose fate is unknown. Therefore no conclusions can be drawn as to the ecological significance of site type or condition of ground squirrels that survived.

Adult male survivors appeared to emerge from hibernation in relatively good condition (Table 4). Overall, there were no significant differences in size and condition of ground squirrels between grass and shrub habitats, although ground squirrels from shrub habitats tended to have more fat

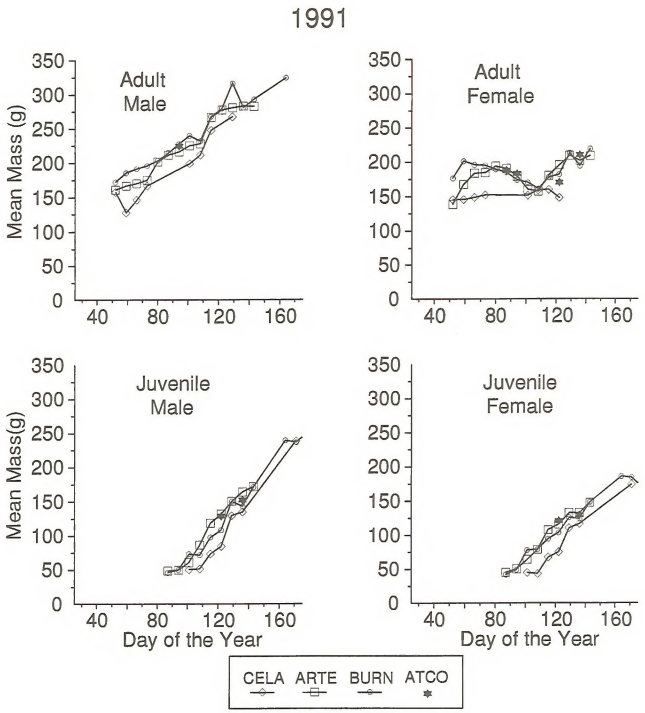

Fig. 2. Townsend's ground squirrel body mass averaged within weeks for site types trapped on the Snake River Birds of Prey Area during 1991. Age and sex classes are shown separately.

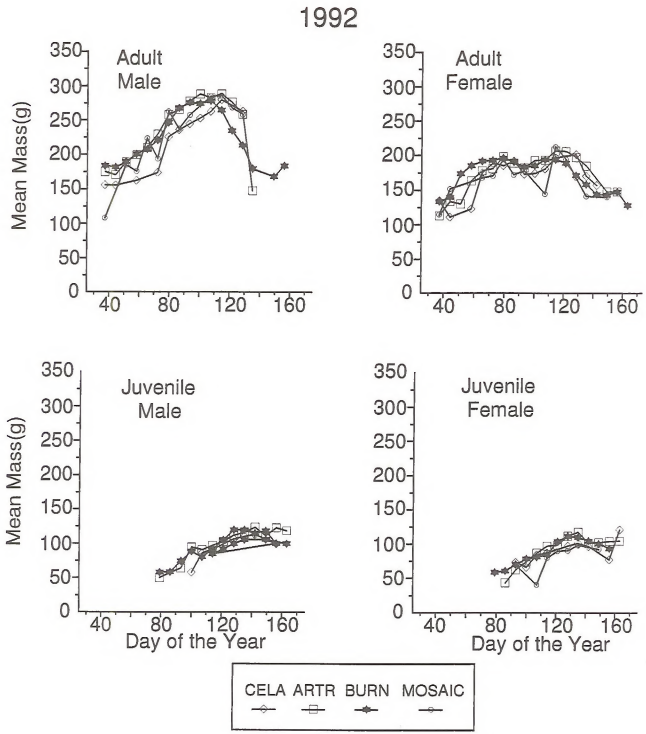

Fig. 3. Townsend's ground squirrel body mass averaged within weeks for site types trapped on the Snake River Birds of Prey Area during 1992. Age and sex classes are shown separately.

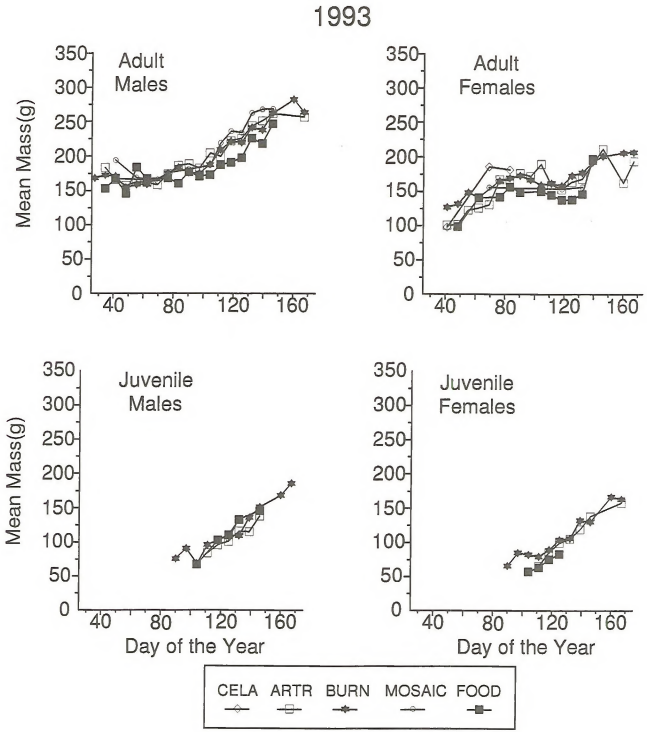

Fig. 4. Townsend's ground squirrel body mass averaged within weeks for site types trapped on the Snake River Birds of Prey Area during 1993. Age and sex classes are shown separately.

(t = 1.654, P = 0.115). Within the grass sites, ground squirrels on the burned, reseeded sites (8a and b) had less lean mass (t = 4.607, P < 0.0005) than those on burned sage sites (4a and b). Within the shrub sites, males on winterfat sites were smaller (1a and b; t = 2.230, P = 0.055) with less lean mass (t = 7.587, P < 0.0005) than those on sage sites, but because they tended to have more fat, they had higher percent body composition composed of fat (t=3.300, P =0.009) than males on sage sites.

Food supplementation of a burned, reseeded site (Site 8a; see Van Horne et al. this volume) did not significantly affect mass or body composition of adult male ground squirrels as compared to animals on the unsupplemented control (Site 8b; Table 5).

The condition of ground squirrels in May varied between grass and sage sites (Table 6). Adult

Table 1. Mean body masses (g) on the day of last capture (first occasion on that day) for Townsend's ground squirrels in the Snake River Birds of Prey Area whose last capture was on or after 1 May in 1991 and in 1992. Sample size in parentheses. Animals found to be present the following year are indicated as 'Recaptured'. Probabilities from pairwise T-tests.

	Adult Males	Adult Females	Juvenile Males	Juvenile Females
1991				
Recaptured	287(31)	209*(52)	170**(62)	142***(136)
Not Recaptured	284(24)	194(24)	149(133)	125(119)
1992				
Recaptured	276***(26)	201**(12)	12*(2)	112(4)
Not Recaptured	239(45)	175(131)	110(263)	103(307)

*P < 0.05
**P < 0.01
***P < 0.001

Table 2. Mean days of the year of last capture for Townsend's ground squirrels whose last capture was on or after 1 May in 1991 and in 1992. Sample size in parentheses. Animals found to be present the following year are indicated as 'Recaptured'.

	Adult Males	Adult Females	Juvenile Males	Juvenile Females
1991				
Recaptured	142**(34)	136(60)	145**(69)	143(148)
Not Recaptured	133(24)	137(27)	141(149)	138(134)
1992				
Recaptured	127*(35)	132(26)	147*(5)	146(5)
Not Recaptured	130(73)	134(208)	137(308)	137(391)

*P < 0.05
**P < 0.01
***P < 0.001

males tended to be bigger ($t = 1.779$, $P = 0.083$) on sage sites than on grass sites, and adult females tended to be larger (lean mass; $t = 1.702$, $P = 0.127$) on sage sites than on grass sites. If the larger number of ground squirrels active on grass sites than sage sites indicates a delayed entry into torpor, then these differences may only be temporal. However, 2 lines of evidence suggest these differences are related to cover type. First, juvenile males were larger on burns (mass: $t = 2.100$, $P = 0.064$; lean mass: $t = 3.414$, $P = 0.007$) than on sage sites. Second, the disparity in numbers of active animals on the 2 cover types was similar in February. These lines of evidence suggest that adult ground squirrels are larger on shrub sites. Alternatively, juvenile ground squirrels on the 2 types of sites may have differing growth rates or phenologies. Another possibility is that supplementation influenced the averages for the grass sites. Supplementation may allow smaller individuals to survive, or may reduce the overall size and condition of ground squirrels as animals immigrate onto the site and competitive interactions increase.

Maximum Running Speed.—Ecologists often attempt to positively correlate body mass of individuals with fitness parameters such as overwinter survival and reproductive success. Sometimes we do not recognize that body mass could be negatively correlated with factors that influence fitness. For instance, ground squirrels living in open environments primarily respond to avian predators by running to a burrow for

Table 3. Characteristics of survivors and ground squirrels with unknown fates in the Snake River Birds of Prey Area overwinter 1992-93. Standard errors in parentheses.

Site type	Age/Sex	Fate	*n*	Mass	Lean	Fat	% fat
Sage	Juvenile Male	Survived	1	104.0	85.9	5.2	17.4
		Unknown	18	109.1	84.2	14.5	19.4
				(5.5)	(0.8)	(3.7)	(4.2)
	Juvenile Female	Survived	1	124	88.8	35.2	28.4
		Unknown	21	107.9	84.8	24.6	17.8
				(4.9)	(0.7)	(3.7)	(4.1)
	Adult Female	Survived	1	176	89.2	86.8	49.3
		Unknown	3	186.0	91.0	95.0	50.8
				(12.3)	(2.3)	(10.0)	(2.1)
Burned/ Reseeded	Juvenile Female	Survived	1	110	85.4	24.6	22.4
		Unknown	28	102.4	85.3	18.8	13.5
				(3.6)	(0.7)	(2.2)	(3.6)
	Adult Female	Survived	1	156	89.2	66.8	42.8
		Unknown	23	165.7	90.3	75.4	45.1
				(3.2)	(0.7)	(2.9)	(1.0)

Table 4. Mass and body composition of adult male Townsend's ground squirrels in the Snake River Birds of Prey Area soon after they emerged from hibernation in 1993.

Site type	*n*	Mass	Lean	Fat	% Fat
Burned	4	172.0	132.4	39.6	22.0
		(11.9)	(1.5)	(11.5)	(5.1)
All Grass Sites	26	161.7	119.9	41.7	25.6
		(3.8)	(2.6)	(2.4)	(1.1)
Sage	7	185.6	135.8	49.9	26.5
		(7.6)	(3.2)	(5.4)	(1.9)
Winterfat	4	166.6	109.4	57.2	34.2
		(3.9)	(1.3)	(3.6)	(1.4)
All Shrub Sites	11	178.7	126.2	52.5	29.3
		(5.7)	(4.5)	(3.7)	(1.7)

Table 5. Effects of food supplementation on total mass, lean mass, and fat mass in grams, and percent of combined fat and lean that is fat, in Townsend's ground squirrels on a burned, reseeded site in the Snake River Birds of Prey Area.

			Supplemented			Control				
Date	Age/Sex		$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	*t*	*P*
Feb	Adult Male	Mass	158.9	7.6	6	154.3	6.7	9	0.457	0.656
		Lean	114.9	5.0	6	113.1	4.7	9	0.254	0.804
		Fat	44.0	4.2	6	41.2	3.5	9	0.509	0.621
		% Fat	27.6	1.9	6	26.5	1.6	9	0.424	0.680
May	Adult Male	Mass	223.2	26.8	15	217.0	15.7	3	0.543	0.611
		Lean	154.2	19.9	15	147.9	7.8	3	0.928	0.379
		Fat	69.0	14.7	15	69.1	8.8	3	-0.023	0.983
		% Fat	30.8	4.7	15	31.9	1.9	3	-0.597	0.567
	Adult Female	Mass	149.5	1.7	8	–	–	0	–	–
		Lean	116.0	1.2	8	–	–	0	–	–
		Fat	33.5	2.2	8	–	–	0	–	–
		% Fat	22.3	1.3	8	–	–	0	–	–
	Juvenile Male	Mass	110.0	9.7	3	112	–	1	–	–
		Lean	102.3	2.7	3	103.9	–	1	–	–
		Fat	7.7	9.3	3	8.1	–	1	–	–
		% Fat	5.5	8.7	3	7.3	–	1	–	–

refuge. Maximum running speed (MRS) should determine, in part, the probability of mortality due to raptors (other factors include probability of encountering a raptor, detection distance of predators, distance from a refuge, reliability of conspecific alarm calls, and possibly experience). MRS is negatively correlated with body mass for Belding's ground squirrels (*Spermophilus beldingi*, Trombulak 1989), but evidently not for golden marmots (*Marmota caudata aurea*, Blumstein 1992).

Our primary question was whether body mass affected MRS. We also were interested in whether distance influenced MRS and possibly interacted with body mass. Our pilot study suffered from the same malady as the ongoing demography study; low densities of squirrels resulted in low trapping success and few data. After several trials to standardize methods, however, we conducted 10 trials with 8 individuals. Three trials included excessive hesitation or non-linear running, so we obtained useful data for 7 trials with 5 individuals (Table 7). MRS for the 0-5 m distance ranged from 2.49 to 4.17 m/sec ($\bar{x}$ = 3.37), and MRS for the 5-10 m distance ranged from 2.19 to 4.20 m/sec ($\bar{x}$ = 3.47). Thus, we found no evidence to suggest a distance effect, at least for the distances and body masses measured. The overall range of MRS for male Townsend's ground squirrels (2.19-4.20 m/sec) was similar to reported MRS for Belding's ground squirrels (3.30-5.40 m/sec, Trombulak 1989) and for male golden marmots (2.45-5.70 m/sec, Blumstein 1992). Compared to the body mass of Townsend's ground squirrels, Belding's ground squirrels are somewhat larger (range: 200-450 g, Trombulak 1989), whereas golden marmots are substantially larger (range: 1,900-4,900 g, Blumstein 1992). Unfortunately, we did not obtain enough data to examine effects of body mass within Townsend's ground squirrels (Table 7).

We think that the design of our MRS study is feasible, but that sample sizes required for valid inferences may be difficult to obtain given the post-drought densities of squirrels. Our observations suggest that there may be within-individual differences in motivation, which are more subtle than the obvious hesitation that we previously described. Such behavior will likely contribute to unexplained variance in our study, but we think adequate sample sizes would allow us to detect body mass and distance effects if they exist.

Grazing Exclosures.—Mean body mass of 8 males in the burn exclosure ($\bar{x}$ = 209 g, SD = 12.0

Table 6. Mass (g) and body composition of Townsend's ground squirrels in the Snake River Birds of Prey Area in May 1993.

Age/Sex	Site type	n	Mass (SE)	Lean (SE)	Fat (SE)	% Fat(SE)
Adult Male	Burned	6	57.7	172.8	84.8	33.0
			(3.1)	(9.1)	(7.3)	(3.0)
	Burned/Reseeded	18	222.2	153.1	69.0	31.0
			(5.9)	(4.3)	(3.2)	(1.0)
	All Grass Sites	24	231.0	158.1	73.0	31.5
			(5.5)	(4.3)	(3.3)	(1.1)
	Sage	19	244.8	164.6	80.3	32.6
			(5.5)	(3.7)	(4.0)	(1.2)
Adult Female	Burned	5	201.8	129.4	72.4	33.5
			(25.0)	(7.4)	(21.8)	(5.6)
	Burned/Reseeded	8	149.5	116.0	33.5	22.3
			(1.7)	(1.2)	(2.2)	(1.3)
	All Grass Sites	13	169.6	121.2	48.4	26.6
			(116)	(3.3)	(9.6)	(2.7)
	Sage	6	176.8	133.3	43.5	24.7
			(3.5)	(6.3)	(5.1)	(2.9)
Juvenile Male	Burned	6	138.5	116.2	22.3	15.3
			(8.6)	(4.8)	(5.0)	(3.1)
	Burned/Reseeded	4	110.5	102.7	7.8	6.0
			(6.9)	(2.0)	(6.6)	(6.2)
	All Grass Sites	10	127.3	110.8	16.5	11.6
			(7.2)	(3.6)	(4.4)	(3.3)
	Sage	3	112.0	98.1	13.9	12.4
			(1.0)	(0.9)	(1.8)	(1.5)
Juvenile Female	Burned	4	130.5	111.2	19.3	14.8
			(7.5)	(8.0)	(5.1)	(3.4)
	Sage	1	105	104.3	0.7	0.7

g) was not different from 8 males captured nearby in the same burn ($\bar{x}$ = 221 g, SD = 23.6 g), or from 5 animals captured in the sagebrush exclosures ($\bar{x}$ = 194 g, SD = 10.4 g). Casual observation indicated that levels of grazing by black-tailed jackrabbits (*Lepus californicus*) in the sagebrush exclosures were very high.

Growth Rates of Captive Litters.—Individuals in the smaller litter gained mass considerably faster than those in the larger litter (Fig. 5). By 8 April, when the young were 29 days old, average mass of young from the smaller litter was 28 g higher than that for the larger litter (87.3 vs. 59.4 g). At this age, the ranges of body mass for the 2 litters did not overlap (Fig. 5). If these few data reflect patterns that may occur in nature, then differences in litter size could produce considerable differences in body mass of juveniles (and movements and probability of capture), even without the observed variation in birth dates. In addition, within litters there was considerable variation in body mass of individuals (<20 g) by 8 April (Fig. 5).

Probably because of the ad libitum diets, the mothers were able to maintain or increase their body mass during lactation (Table 8). Also, despite the substantial differences in growth rates of individuals between the 2 litters, the total masses of the litters were similar (Table 8). We infer that, even on an ad libitum diet, there is a limit to the energy that mothers can provide to the litters, and this amount is partitioned among the young.

At 7 days old, young in both litters had some very short hair; they had eye slits present, but their eyes were not open. By 11 days old, their eyes were still not open, but they had become fairly vocal. Young in Litter A (8 young) had short hairs on their dorsal sides, whereas the young in Litter B (6 young) had short hairs over most of their body. By 18 days old, the young in both litters had a full pelage. The young in Litter B opened their eyes at 20 days old, and the young in Litter A opened their eyes at 22 days. The young became increasingly mobile after opening their eyes, and we observed them eating

Table 7. Maximum running speeds of Townsend's ground squirrels, Snake River Birds of Prey Area, 1993. Speeds are for adult males from controlled time trials conducted in the field. The 2 split times are from 1 10-m run.

Animal No.	Date	Body mass	Maximum running speed (m/sec)	
			0-5 m split	5-10 m split
A1	14 April	182	2.49	2.58
A2	14 April	203	2.56	2.19
A3	14 April	175	3.11	3.82
A3	2 May	206	3.52	4.20
A3	19 May	212	4.07	3.91
A7	19 May	219	4.17	4.00
A8	19 May	226	3.68	3.57

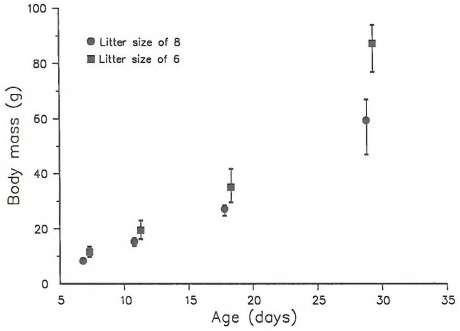

Fig. 5. The relationship between mean body mass and age for 2 litters of Townsend's ground squirrels from a burned site in the Snake River Birds of Prey Area born in captivity during 1993.

apples. In general, the young in the smaller litter developed somewhat faster than those from the larger litter.

Vegetation

Shrubs.—Structural characteristics and density of shrubs differed among sites (Table 10). The inter-site patterns were similar to those previously reported (Van Horne et al. 1992), with average heights of shrubs increasing among sites in the following order: winterfat < winterfat-sage mosaic < sagebrush inside OTA < sagebrush outside OTA. Densities of shrubs were greater on the winterfat sites than on the mosaics and sage-dominated sites (Table 10). Differences in cover among sites probably determine, in part, the ability of squirrels to detect predators visually (Sharpe and Van Horne, this volume), and therefore may influence predation risk and behavior of squirrels.

Experimental Tracking.—Experimental tracking may have increased the density of shrubs and decreased the mean height of shrubs (Table 9). The frequency distributions of shrub heights indicated that these changes can be partly explained by an increased number of small (<13 cm) shrubs on site 9a after tracking. We doubt that such changes represent any meaningful difference to squirrels in terms of microclimate and predator detection. Similarly, the pre-treatment variation (1991 vs. 1992) within sites was considerable, especially for shrub height, so caution should be used in interpreting only 1 year of post-treatment data. The percent of individual shrubs classified as alive (green leaves present) or dead (no green leaves; evidently dormant, dying, or dead) showed no consistent temporal trends that would indicate a tracking effect. Our perception

Table 8. Mass of 2 female Townsend's ground squirrels and their litters. The females were captured on a burned site in the Snake River Birds of Prey Area, 1993. Litters were born in captivity and housed in non-laboratory conditions.

	Body Mass (g)		Total Mass of Litter (g)	
Date	Female A[a]	Female B[a]	Female A	Female B
17 March	168	197	67.2	69.3
21 March	186	204	122.9	117.2
28 March	198	205	217.4	211.0
8 April	184	202	475.0	524.0

[a]Female A had a litter size of 8, and Female B had a litter size of 6.

Table 9. Shrub density (no./ha) and height (cm) at 4 sage sites inside the Orchard Training Area (OTA), 1991-93. Variables were measured in late February or early March each year. The treatment was experimental tracking by an M-1 armored vehicle on 26-27 June, 1992. Values presented are the differences for controls (5a, 5b) minus treatments (9a, 9b).

		Pre-treatment		Post-treatment
Variable	Comparison	1991	1992	1993
Shrub density	(5a - 9a)	1.9	1.2	-0.9
	(5b - 9b)	-0.4	-0.3	-2.2
	$\bar{x}$[a]	0.75	0.45	-1.55
Shrub height	(5a - 9a)	0	-14.1	9.6
	(5b - 9b)	-0.6	3.3	5.5
	$\bar{x}$[a]	-0.3	-5.4	7.55

[a]Means are for the 2 control-treatment pairs (5a and 9a, 5b and 9b), which were spatially matched.

Table 10. Structural characteristics and density of shrubs on 10 Townsend's ground squirrel study sites[a], Snake River Birds of Prey Area, 7-10 March, 1993.

	Height (cm)			Volume (dm^3)[b]			Density (no./m^2)		
Site	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE
1a	570	16.3	0.26	570	7.8	0.422	15	5.4	0.22
1b	454	19.7	0.32	454	11.9	0.572	15	4.3	0.25
2a	84	71.5	3.45	84	470.3	60.22	15	0.8	0.12
2b	173	60.5	2.02	173	254.9	32.72	15	1.6	0.24
3a	457	18.7	0.98	457	43.0	7.75	22	2.9	0.55
3b	357	33.1	1.35	357	82.7	10.24	22	2.3	0.48
5a	138	41.9	1.80	138	113.9	14.75	15	1.3	0.10
5b	160	38.9	1.46	160	89.1	10.12	15	1.5	0.21
9a	228	32.3	1.56	228	92.0	16.83	15	2.2	0.30
9b	390	33.4	0.82	390	81.9	5.76	15	3.7	0.25

[a] The other 10 sites were burns with few ($\leq$0.13 individuals/m^2) or no shrubs.

[b] Shrub volume is an index calculated from height (h), maximum radius (a), and the radius perpendicular to the maximum radius (b). Volume = h(3.1416*a*b).

from observations in the field was that the experimental tracking did break enough branches on individual shrubs to produce detectable tracks across the sites, but probably did not alter the habitat substantially on a site-scale. One obvious exception to this general impression, however, was on the edge of sites where the turning of the armored vehicles caused mortality of shrubs, and habitat changes that may be long-term.

Phenology.—Seasonal changes of 2 species (*Poa secunda* and *Ranunculus testiculatus*) demonstrate the typical phenology patterns between a drought year (1992) and a non-drought year (1993). *P. secunda* was the most common grass on most sites during both years, and it is a common item in the diet of squirrels. *R. testiculatus* was the most common forb on several sites, especially the OTA sage sites, and it is also eaten by squirrels. In our analyses, we have used the dates when most (>50%) individuals reached a phenological stage, because these dates probably are most relevant to foraging squirrels. There was a major shift in the phenology of *P. secunda* and *R. testiculatus* between 1992 and 1993 (Fig. 6). *P. secunda* matured in February to early March in 1992, but not until late March to mid-April in 1993 (Fig. 6). Similarly, *R. testiculatus* matured in mid March in 1992, but not until early April in 1993 (Fig. 6). We think this annual difference can be explained, in part, by the relatively late winter of 1993, which seemed to delay the growth of most plant species on our sites.

The dates when most individuals of *P. secunda* and *R. testiculatus* began withering and drying also differed by 3-4 weeks between years (Fig. 6). For instance, *P. secunda* was generally withering on most sites by late April or early May in 1992, but not until late May in 1993 (Fig. 6). Most above-ground growth of *P. secunda* was desiccated by mid to late May in 1992 (Fig. 6), whereas we were unable to obtain accurate estimates for this stage for 1993, because *P. secunda* still had some succulent growth on most sites on the last day that we recorded phenology. We think these annual differences are a result of the drought in 1992, which truncated the growing season of many species on our sites.

Vegetation Cover.—The inter-year patterns in seasonal changes of percent cover of vegetation coincided with results from our phenological observations. For instance, the percent cover of succulent *P. secunda* differed markedly between 1992 and 1993 (Fig. 7). In 1992, the coverage by *P. secunda* decreased from early season to mid-April on burned sites, and it was relatively stable on

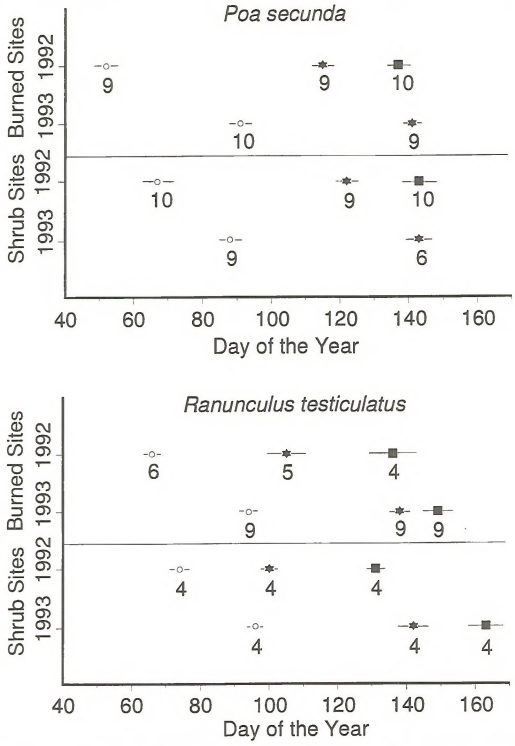

Fig. 6. The phenology of 2 major food species for Townsend's ground squirrels on the Snake River Birds of Prey Area, *Poa secunda* and *Ranunculus testiculatus*, between 1992 and 1993, for burned and shrub-dominated habitats. Open circles indicate dates at which 50% of individuals were mature, and closed stars indicate dates at which individuals began to wither and dry. Closed squares indicate dates at which most individuals had withered and dried; we do not have these data for *P. secunda* in 1993. Numbers are sample sizes (# of sites).

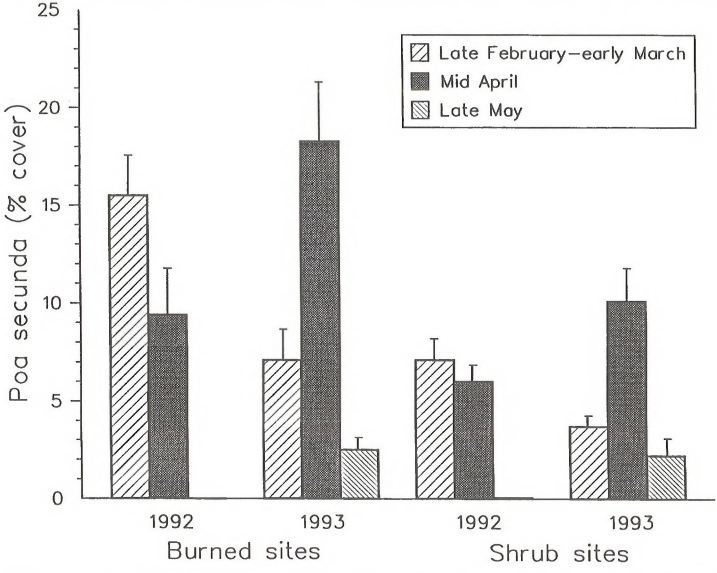

Fig. 7. Percent cover of *Poa secunda*, a major food of Townsend's ground squirrels in the Snake River Birds of Prey Area, during 3 sampling periods in 1992 and in 1993.

shrub sites (Fig. 7). By late May, however, there was <0.05% coverage of *P. secunda* on burned and shrub sites. Compared to 1992, the coverage by *P. secunda* in 1993 was reduced by about 50% in early season, but it increased substantially in mid-April (Fig. 7). By late May in 1993, there was still some succulent *P. secunda* present. The seasonal patterns for *R. testiculatus* were similar to those for *P. secunda*. In 1992, coverage of succulent *R. testiculatus* was stable or decreased from early season to mid April, and it was completely absent by late May. In 1993, the coverage of *R. testiculatus* increased markedly from early season to mid April, and there was still some present in late May.

Several species of exotic annuals also responded to the above average precipitation in 1993. The most dramatic changes were for tansymustards (primarily pinnate tansymustard, *Descurainia pinnata*). The coverage of succulent *D. pinnata* increased substantially during the year on burned sites (early March: 0%; mid April: 1.7%, SE = 0.23, n = 10; late May: 12.9%, SE = 1.82, n =10) and on shrub sites (early March: 0%; mid April: 2.4%, SE = 0.77, n = 10; late May: 8.1%, SE = 2.5, n =10). In contrast, the coverage of succulent *D. pinnata* was <1.0% on all sites during all 3 sampling periods in 1992. *Bromus tectorum* (cheatgrass) also had a growth flush in 1993 on several sites. The most striking changes occurred on Site 6a, where the coverage of succulent *B. tectorum* greatly increased with time (early March: 1.6%, mid April: 27.8%, late May: 45.5%).

In general, there were major seasonal differences in vegetation on our sites between 1992 and 1993. Little succulent plant material was available to juvenile squirrels (and lactating females) at a key time in their annual activity period in 1992. The degree of seasonal variation that we have documented may increase the variance in correlations of vegetation coverage with densities of squirrel holes (Study 5). When vegetation is sampled only once each year, generally very late in the active season for squirrels, some plant species are probably underrepresented (and others overrepresented) relative to their availabilities at key times of the annual cycle of Townsend's ground squirrels.

Diet

Fecal Analysis.—Diets on the winterfat sites in 1992 contained a high proportion of *C. lanata*, particularly late in the season when the proportion of the diet that was *P. secunda* dropped markedly (Fig. 8). The early-season diet on sage sites was composed almost entirely of *P. secunda*, whereas the proportion comprised of *A. tridentata* was highest in mid-season. "Other" foods (primarily forbs) increased in importance as the season progressed. Similarly, on burned sites the early-season diet was almost entirely *P. secunda*, and the proportion of 'Other' increased through the season. On winterfat/sage mosaic sites the diet was similar to that on winterfat sites, except that *P. secunda* comprised a larger share of the late-season diet (Fig. 8). Overall patterns of difference among sites and between early and late samples are similar to those reported for 1991 (Van Horne et al. 1992).

Forage Selection.—Table 11 summarizes the data from collected squirrels for forage quality analyses. Results of these analyses will be presented in next year's final report and compared with behavioral observations.

Fat Deposition Patterns.—Few significant differences were found in the adipose tissue fatty acid composition of ground squirrels from sage or burned sage sites in March (Table 12) or in May (Table 13). These results support the hypothesis that differences in fatty acid composition found in the tissues of ground squirrels from different sites during the severe drought of 1992 (Van Horne et al. 1992) were a consequence of dietary variation among sites. But, contrary to expectation, the fatty acid profiles found in 1993, were not similar to those of sage-dwelling ground squirrels in 1992 (Van Horne et al. 1992, Table 27). We had predicted that ground squirrels in moist years would fatten on the large amounts of green vegetation available, which is high in linolenic acid (see below). However, linolenic acid levels in 1993 did not approach those found in tissues of sage residents in 1992 (Van Horne et al. 1992, Table 27). Either ground squirrels on sage sites in 1992 obtained their 18:3 fatty acids from a source other than green plants, or ground squirrels in 1993 fattened on diets composed of something other than a large amount of green vegetation.

Plant fatty acids are dominated by linolenic acid (18:3) when plants are green, as in winterfat or grass blades (Table 14), but dominated by linoleic acid (18:2) when they are dry, as in bluegrass crowns. That ground squirrels on burned sites stored substantial amounts of linoleic acid in

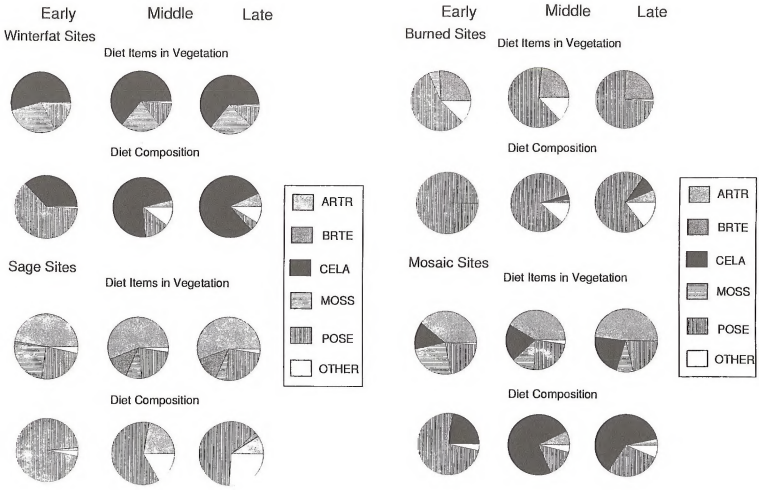

Fig. 8. For each habitat type trapped on the Snake River Birds of Prey Area, and for each sampling period in 1992, percent composition of plant types in feces of Townsend's ground squirrels is averaged across sites. These are compared with relative percent cover on the trapping sites of all plants that appear in ground squirrel diets, sampled during the same time period.

grass blades (Table 14), but dominated by linoleic acid (18:2) when they are dry, as in bluegrass crowns. That ground squirrels on burned sites stored substantial amounts of linoleic acid in 1992 is not surprising—their diets likely consisted almost exclusively of grass crowns. Similarly, it was reasonable to expect ground squirrels from sage sites to have substantial amounts of linolenic acid, since grass was still green and relatively abundant in the shade of sagebrush bushes when tissues were collected for analysis. (Although this expectation may have

Table 11. Wet and dry stomach weight, water content of stomach contents, and percent of overall body weight from stomach samples of Townsend's ground squirrels in the Snake River Birds of Prey Area, March and May 1993.

	Stomach Weight								
	Wet		Dry		% Water		% of Body Wt		
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	Range
MARCH									
Burned Sagebrush (n=11)	12.9	2.7	3.2	0.8	76.9	1.2	7.5	1.4	1.2-15.3
Sagebrush (n=11)	6.5	1.7	1.4	0.4	80.9	1.0	3.8	1.0	1.1-11.8
MAY									
Burned Sagebrush (n=4)	9.0	2.6	2.1	0.8	78.5	2.2	5.4	1.9	2.3-10.8
Sagebrush (n=7)	6.6	1.3	1.6	0.2	75.4	1.3	4.7	0.7	2.6-9.9

Table 12. Fatty acid composition of Townsend's ground squirrels collected from burned sites and sage sites on the Snake River Birds of Prey Area in March 1993.

	Burn Sites			Sage Sites				
Fatty Acid*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	*t*	*P*
8:0	0.78	0.35	3	0.54	0.12	6	0.110	0.568
10:0	0.11	0.02	6	0.09	0.01	5	0.913	0.385
12:0	3.75	0.30	7	1.61	0.08	6	6.788	<0.0005
14:0	0.72	0.41	7	0.43	0.07	6	0.724	0.504
16:0	18.04	1.44	7	17.08	1.00	6	0.546	0.596
16:1	2.22	0.23	7	2.12	0.24	6	0.256	0.803
17:0	0.34	0.02	6	0.57	0.04	6	-4.837	0.001
17:1	0.36	0.02	6	0.40	0.05	6	-0.626	0.552
18:0	2.60	0.16	7	2.68	0.27	6	-0.250	0.808
18:1	31.39	4.00	7	32.85	2.23	6	-0.319	0.757
18:2	15.33	4.33	7	12.15	0.80	6	0.724	0.495
18:3	23.79	3.41	7	25.29	1.43	6	-0.405	0.696
20:0	0.25	0.10	3	0.36	0.12	5	-0.709	0.506
20:1	–	–	0	0.41	0.07	6	–	–
20:2	–	–	0	0.24	0.10	2	–	–
20:3	–	–	0	0.25	0.02	4	–	–
20:4	0.45	0.04	5	0.54	0.10	6	-0.775	0.464
22:6	0.55	0.02	2	0.41	0.11	6	1.200	0.281

*Number of carbons in fatty acid carbon chain : number of double bonds

Table 13. Fatty acid composition of Townsend's ground squirrels collected from burned sites and sage sites on the Snake River Birds of Prey Area in May 1993.

Fatty Acid[a]	Burn Sites $\bar{x}$	SE	n	Sage Sites $\bar{x}$	SE	n	t	P
8:0	0.70	0.46	4	0.36	0.15	6	0.681	0.537
10:0	0.08	0.01	3	0.17	0.09	5	1.650	0.158
12:0	1.65	0.16	4	1.61	0.31	6	0.115	0.911
14:0	0.29	0.02	4	0.35	0.05	6	-1.162	0.288
16:0	17.29	0.82	4	17.87	0.96	6	-0.460	0.658
16:1	2.24	0.36	4	2.04	0.25	6	0.462	0.661
17:0	0.52	0.03	4	0.71	0.04	6	-3.865	0.005
17:1	0.34	0.04	4	0.46	0.10	6	-1.149	0.293
18:0	2.58	0.36	4	2.63	0.11	6	-0.130	0.904
18:1	32.32	2.74	4	33.81	4.43	6	-0.287	0.782
18:2	10.57	0.67	4	10.32	0.03	6	0.244	0.813
18:3	28.34	2.93	4	26.20	3.86	6	0.443	0.670
20:0	0.18	0.02	3	0.17	0.20	5	0.509	0.632
20:1	0.12	0.05	3	0.16	0.01	2	-0.642	0.586
20:2	0.14	0.02	2	0.27	0.14	3	-0.910	0.456
20:3	0.28	0.03	4	0.33	0.03	6	-1.015	0.342
20:4	0.50	0.08	4	0.47	0.04	6	0.380	0.720
22:6	0.22	0.04	4	0.20	0.02	6	0.300	0.776

[a]Number of carbons in fatty acid carbon chain : number of double bonds

Table 14. Mean relative percent composition across sites (n) of the most abundant fatty acids of plant foods of Townsend's ground squirrels prior to entry into torpor in 1992.

Fatty Acids[a]	Winterfat Leaves $n = 2$ (SE)	Sage Leaves $n = 2$ (SE)	Bluegrass Crowns $n = 3$ (SE)	Squirreltail Blades $n = 1$	Bluegrass Blades $n = 1$
16:0	20.74 (1.38)	10.33 (0.55)	12.80 (0.08)	22.16	27.43
16:1	1.45 (0.24)	6.33 (0.08)	1.85 (0.25)	2.51	1.40
18:0	1.85 (0.68)	52.62 (3.31)	2.02 (0.25)	1.63	2.31
18:1	9.61 (0.22)	4.59 (0.93)	28.90 (2.28)	2.74	3.77
18:2	13.47 (0.29)	8.67 (0.57)	45.05 (0.86)	11.16	12.81
18:3	55.25 (2.37)	17.46 (2.32)	9.39 (1.31)	59.79	52.28

[a]Number of carbons in fatty acid carbon chain : number of double bonds

been met only spuriously, given the 1993 patterns noted above). The site for which diet and plant fatty acid profile did not match in 1992 was the winterfat type. Our fecal sample indicated that ground squirrels on winterfat sites ate large amounts of winterfat, high in linolenic acid, however, tissues consisted of fatty acid profiles very similar to those of animals eating grass crowns. This could be due to bias in estimates of winterfat's importance in the diet. The discrepancies between diet fatty acid profiles and tissue fatty acid profiles may be understood better after completion of 1993 diet and plant fat analyses.

The Role of Fats in Laboratory Animals.—The diet formulations used in 1993 caused large differences in the fatty acid composition of ground squirrel adipose tissue (Table 15). Ground squirrels fed the high PUFA diet had more linoleic acid, which is 64% of sunflower oil. Those fed the low-PUFA diet had more medium chain fatty acids (particularly decanoic acid[10:0], lauric acid [12:0], and palmitic acid[16:0], which are common in hydrogenated coconut oil (for example 12:0 is 48% of coconut oil) and can be produced by the ground squirrels through biosynthesis of fats. We will test the effects of these treatments on torpor bout duration at the end of hibernation.

Cafeteria Tests.—The 3 main food items present in ground squirrel diets both early and late in the season are *Poa secunda*, *Ceratoides lanata*, and *Artemisia tridendata* (Van Horne et al. 1992; also see "Fecal Analysis" results above). Because the latter 2 species are perennial desert shrubs, they probably contain more protein-complexing secondary compounds, and perhaps toxins, than does the perennial grass. We have noted that animals from sage sites eat more *A. tridentata* than those from other sites, and animals from winterfat sites eat more *C. lanata*. We thought it possible that animals from the shrubby sites might exhibit short- or longer-term changes to their digestive tract that improved their ability to extract useful substances from the shrub foods. Thus we predicted that animals from shrubby sites would have a relatively greater preference for shrub foods.

In February 1993 we collected data from 8 animals on 12 occasions (1 animal in 1 24-hr treatment). On 9 of these occasions the animals consumed sufficient food to meet our experimental criterion; 1 of these did not have dry weight information. The mean total wet weight of plant material (± SD) consumed by these animals was 9.08 ± 3.453 g. Mean proportion of wet weight

Table 15. Fatty acid composition of adipose tissue of captive Townsend's ground squirrels fed diets high or low in Polyunsaturated Fatty Acids (PUFAs).

	High PUFA			Low PUFA				
Fatty Acid*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	*t*	*P*
8:0	0.52	0.13	8	0.41	0.05	7	0.819	0.434
10:0	0.13	0.03	6	6.14	2.45	7	-6.485	0.001
12:0	1.00	0.07	8	8.24	0.64	7	-11.275	<0.0005
14:0	0.18	0.03	7	0.57	0.02	7	-10.596	<0.0005
16:0	14.76	0.41	9	20.84	0.23	7	-12.929	<0.0005
16:1	2.48	0.16	9	4.36	0.21	7	-7.091	<0.005
17:0	0.48	0.04	9	0.49	0.04	7	-0.186	0.855
17:1	0.32	0.02	9	0.45	0.06	7	-1.829	0.106
18:0	3.01	0.60	9	2.21	0.3	7	1.161	0.268
18:1	40.15	0.79	9	43.65	1.37	7	-2.214	0.052
18:2	33.69	1.06	9	9.11	0.31	7	22.336	<0.0005
18:3	1.08	0.04	9	0.97	0.02	7	2.677	0.021
20:0	0.24	0.12	2	–	–	0	–	–
20:1	0.32	0.04	2	0.31	–	1	–	–
20:2	0.18	0.01	6	–	–	0	–	–
20:3	0.57	0.13	9	0.51	0.06	5	0.433	0.673
20:4	0.32	0.09	7	0.36	0.08	2	-0.315	0.766
22:6	0.25	0.01	6	0.31	0.01	7	-3.814	0.003

*Number of carbons in fatty acid carbon chain : number of double bonds

animals was 3.4 g. Mean proportion of dry weight consumed (± SD) was highest for *C. lanata* (0.55 ± 0.163), second for *P. secunda* (0.28 ± 0.212), and least for *A. tridentata* (0.18 ± 0.104). Mean weight loss of the animals was 16.3 g/day (SD = 1.60 g/day).

In March we collected data from 14 animals on 14 occasions. Eight animals met minimum consumption criteria; 5 of these did not differ from burned sites and 3 from sage sites. The mean total weight of plant material consumed by these animals was 3.5 g (dry) or 8.8 g (wet). Mean (± SD) wet weight proportions of *P. secunda*, *C. lanata*, and *A. tridentata* consumed by animals from burned sites (0.73 ± 0.078, 0.22 ± 0.079, and 0.05 ± 0.047, respectively) did not differ from proportions consumed by animals from sage sites (0.82 ± 0.089, 0.17 ± 0.084, and 0.01 ± 0.007, respectively).

Proportions of the available food types consumed were consistent. Animals did not ingest sufficient calories to maintain weight. This could be either because the food offered was of inadequate quality, or because the animals were not comfortable in the cage environment. Both experiments were conducted early in the season, before new leaves appeared on the *A. tridentata* and the *C. lanata*, so these may have been less palatable than they were later in the season. Animals from the sage sites may have been eating primarily *P. secunda* at this time, so we may not have adequately tested the preferences of animals from different habitats. The experiment does indicate that *P. secunda* was a preferred food during late winter and early spring of 1993, but that dry weight consumption of *C. lanata* was higher. This suggests that *P. secunda* may be favored for water content, and perhaps certain vitamins and nutrients, while *C. lanata* provides more concentrated foods and perhaps a larger contribution of fat. Although *A. tridentata* was not preferred in these trials, it does appear substantially in the diet and we have seen animals climbing these shrubs to forage on the leaves. Squirrels may eat only new growth appearing later in the season.

Genetics

We collected DNA material by tail clipping from 35 individuals. The samples were distributed fairly evenly among collection areas (Area I = 13 samples, Area II = 10, Area II = 12) and between the sexes (18 males, 17 females). Most samples were from adults (26 of 35). The samples from juveniles were from individuals that we assumed were born in the area where they were collected. We presumed they were not long-range immigrants based on their small body masses (62-98 g). Telemetry data should allow us to test this assumption.

We collected an additional 26 off-site animals (Area I = 11, Area II = 15). This sample also was primarily adults (20 of 26), but was male-biased (18 males, 8 females). Therefore, overall we collected material for genetic analysis from 61 individual Townsend's ground squirrels (Area I = 24 samples, Area II = 10, Area III = 27).

PLANS FOR NEXT YEAR

We expect that densities will be very low. We will continue to monitor body mass and body composition, and to collect fecal samples for diet analysis. As in 1993, we will sample vegetation 3 times. We will repeat tests of the relationship between body mass and running speed using a wider range of body masses. We will collect stomach samples from a wider variety of habitat types than sampled in 1993 at 2-3 times during the season to determine shifts in forage use and forage quality.

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(IDARING) assisted in the field with vegetation identification. Dr. Mary Harris of the Department of Foods and Human Nutrition at Colorado State provided guidance and laboratory facilities for fatty acid characterization. Symm's Fruit Ranch donated apples for bait.

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Behavior of Townsend's Ground Squirrels in Different Habitat Types

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ANNUAL SUMMARY

*During the third field season (January-June 1993) of the planned 4-yr study we continued to collect information that will help us describe behavioral differences among habitat types for Townsend's ground squirrels (**Spermophilus townsendii**). Behavioral data were collected on 6 study sites that differ in vegetation type, fire history, and history of tracking by armored vehicles. A general increase in levels of vigilance across sites from 1992 to 1993 may have resulted from denser vegetation and more frequent visits by raptors. At the same time, the ground squirrels may have required less time for foraging because higher levels of precipitation increased forage availability. Animals spent more time foraging on burned sagebrush (**Artemisia tridentata**) and sagebrush sites, and more time being vigilant on winterfat (**Ceratoides lanata**) and winterfat/sagebrush mosaic sites. Experimental tracking by armored vehicles had no detectable short-term effect on observed behavior.*

We developed a measure of the climate space encountered by this species. During clear, sunny conditions the microclimate in the open is outside the thermal neutral zone of a Townsend's ground squirrel between 1200 and 1900 hrs.

We verified the design of a proposed experiment to explore relationships between levels of vigilance and vegetation cover by experimentally manipulating shrub cover. We developed and quantified an index of predator detection in each habitat type. We found that ground squirrels in burned sagebrush habitats can detect predators at a greater distance, and those in sagebrush/winterfat mosaic at a lesser distance, than ground squirrels in the other habitat types. Animals in sagebrush habitat can detect predators at a greater distance than those in winterfat from a standing posture, but not from a sitting or picket pin posture.

To aid in the interpretation of hole counts as a measure of ground squirrel abundance across habitats we conducted a pilot study of hole use using fluorescent powder. The number of holes used by a single individual ranged from 1 to 12.

OBJECTIVES

1. To continue to make significant progress towards the goals of determining whether Townsend's ground squirrel behavior differs:
   a) among age or sex classes,
   b) among habitat types,
   c) between burned and unburned areas,
   d) between areas that have been recently tracked by armored vehicles and those that have not.

2. To understand the role that microclimate plays in influencing Townsend's ground squirrel behavior.

3. To describe how aspects of burrow morphology and burrow use by ground squirrels vary among habitats, and to evaluate the usefulness of holes as indicators of Townsend's ground squirrel density.

METHODS

Study Sites

Behavioral observations were made on 6 sites representing different habitat types, fire history, and armored vehicle tracking history. These include sites 1a, 3b, 4a, 5b, 9b, and 10a in Table 1 of Van Horne et al. (this volume). Figure 1 of that report shows site locations.

Behavioral Observations

Activity Budgets.—We (usually P. B. Sharpe) collected data on Townsend's ground squirrel behavior from 7 February through 14 June 1993. Most observations were made on ground squirrels that had been uniquely marked with hair dye (Clairol Nice 'n Easy® blue-black) on the 6 sites described above. On sites 1a and 3b there were few marked individuals, so we often observed unmarked animals. We often recorded observations of juveniles of unknown sex for similar reasons.

Behavioral observations were made from a portable 3-m hunter's stand (Hunter's Equipment, Inc., San Angelo, TX) using a 15-60 zoom spotting scope mounted on the stand's railing. We recorded the focal animal's behavior, distance to cover, distance to the most recently used burrow (if known), and distance moved at 20-sec intervals on a Polycorder electronic notebook (Omnidata International, Inc., Logan, UT). At the beginning of each observation period and at 15-min intervals thereafter, we also recorded temperature, wind speed, and percent cloud cover. Each focal animal was observed for a minimum of 10 min per day and a maximum of 30 min per day. We discontinued observations if the focal animal disappeared into the burrow for >5 min or was out of sight for >3 min. If 30 min of observations were not collected for a focal animal, we attempted to relocate the individual during the day for further observations. At 15-min intervals (or at the end of an observation period) a scan sample was made to determine the proportion of the day in which animals were active. We scanned only within a specified area on Sites 4a and 10a (usually certain quadrants within the grid that we could easily observe), and did not scan shrub-dominated sites because of the difficulty of detecting active animals. We assessed relative predation pressure from raptors by recording the number and species (if known) of raptors seen flying over the site during each 15-min interval. Additional observations or comments were recorded on a microcassette for later transcription.

We summarized mean proportions of time spent in each activity for each animal, and these were arcsine-transformed prior to analysis. Only observations in which the animal was visible were included in calculations. When testing for age or sex differences, each sample point represented the mean value for a single animal of known age or sex. Data from all observed animals were used when comparing sites or site types. We used ANOVA to test for differences among site, site type, year, age, and sex classes. Significant ANOVA's were investigated using Tukey's Studentized Range Test.

Environmental Factors.—We measured temperature, wind speed, relative humidity, and solar and thermal radiation throughout the day in conjunction with the behavioral observations to identify relationships between environmental conditions and ground squirrel activity. All equipment was obtained from Campbell Scientific, Inc., Logan, UT as described in Van Horne et al. 1992.

In addition to the weather equipment, we used hollow bronze mounts of ground squirrels covered with a ground squirrel pelt to measure the

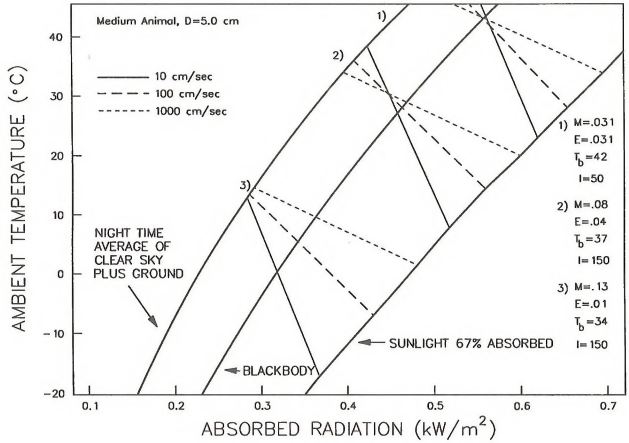

Fig. 1. Climate diagram for a medium Townsend's ground squirrel. Each of the 3 numbered groups of lines was calculated with the values of M, E, I, and T_b indicated in the legend. The solid, dashed, and dotted lines in each of the 3 groups were calculated at low, medium, and high wind speeds as shown in the legend. Lines in group (1) were calculated with values for M, E, I, and T_b that correspond to maximum adjustments of the animals to high temperatures. The lines in group (3) were calculated with values that correspond to maximum adjustments to low temperatures. In group (2) intermediate values were used that might occur near the thermal neutral zone of slightly active animals. The combinations of T_a and Q_{abs} along line AB in group (1) are the maximum combinations in which a Townsend's ground squirrel with a 5 cm diameter could maintain thermal equilibrium when the wind speed was 10 cm/s. The same squirrel could maintain thermal equilibrium at maximum combinations of T_a and Q_{abs} along line CD if the wind speed were 100 cm/s, or along line EF if the speed were 1000 cm/s. The lowest combinations of T_a and Q_{abs} that the squirrel could withstand are represented by the lines in group (3) (Morhardt and Gates 1974).

true environmental temperature (T_e) described by Bakken and Gates (1975). We used these data to create climate-space diagrams that represent combinations of the 4 dimensions: radiation, air temperature, wind speed, and humidity, in which an animal can maintain equilibrium (e.g., Porter and Gates 1969). The values for minimum absorbed radiation (night time average of clear sky plus ground), blackbody radiation, and maximum absorbed radiation (sunlight 67% absorbed; Fig. 1) were obtained from values calculated by Porter and Gates (1969). We sent a ground squirrel pelt to W. Porter for spectrophotometry to determine the absorptivity of ground squirrels to shortwave radiation. We assumed the maximum percentage of radiation absorbed to be 67%, the mean of the midventral and middorsal absorptivity values (60% and 74%, respectively). To form the upper and lower boundaries to the climate space diagram we used the energy-budget equation in the form

$$Q_{abs}=\varepsilon\sigma T_r^4+k(V^{1/3}/D^{2/3})(T_r-T_a)+E-M \quad (1)$$

where Q_{abs} is the radiant energy absorbed by the animal's surface; $\varepsilon\sigma T_r^4$ is the energy reradiated from the animal's surface where ε is the emissivity of the surface (assumed to be 1.0), σ is the Stefan-Boltzman constant, and T_r is the absolute temperature of the animal's surface. Convection involves k, a constant to adjust units and to account for boundary layer effects of air flowing past the object (approximated as a smooth cylinder oriented perpendicular to the wind), windspeed (V), the diameter of the animal (D), and the difference between the animal's surface temperature and ambient temperature (T_r-T_a). E represents evaporation and M represents metabolic heat input. As in Porter and Gates (1969), V is expressed in cm/s; D in cm; T_r and T_a in degrees Kelvin for computations, but degrees Celsius for discussion. We report all remaining values in kW/m^2.

The values for metabolism, evaporation, maximum tolerable body temperatures, and insulation were either calculated or taken directly from the work of Hudson et al. (1972) and Hudson and Deavers (1973). We had estimates of metabolism, evaporation, and conductance so T_r was calculated by

$$T_r = (M-E-CT_b)/-C \quad (2)$$

that was modified from an equation used by Morhardt and Gates (1974) to calculate the conductance of Belding ground squirrels (*S. beldingi*).

The following values were used in Eq. (1) to calculate Q_{abs} for ambient temperatures of 0° and 30° C and windspeeds of 10, 100, and 1000 cm/s as described by Morhardt and Gates (1974):

D=3.5, 5.0, and 6.4 cm;
I=50 and 150 °C m^2 kW^{-1};
M=0.031, 0.08, 0.13 kW/m^2;
E=0.031, 0.04, 0.01 kW/m^2;
T_b=42, 37, 34 °C.

We calculated the value for absorbed radiation both from the meteorological data and from the taxidermic mounts. Using meteorological data we calculated absorbed radiation using the equation described by Morhardt and Gates (1974):

$$Q_{abs}=azS+0.5[as+ar(S+s)+R_e+R_a] \quad (3)$$

where Q_{abs} is the average radiation absorbed by the animal representation (a cylinder with a diameter of 3.8 cm and length of 17.0 cm for a 200 g, standing ground squirrel), a is the average absorptivity of the pelt, z is the proportion of the projected area of the ground squirrel to the total surface area (see Morhardt and Gates 1974 for calculations), S is direct solar radiation, s is reflected solar radiation, r is reflectivity of the substrate to solar radiation, R_a is thermal radiation from the ground, and R_s is thermal radiation from the atmosphere.

Radiation absorbed by the taxidermic mounts was calculated using the equation:

$$Q_{abs}=\varepsilon\sigma(T_e+273)^4+h_c(T_e-T_a), \quad (4)$$

where T_e is the temperature of the mount and h_c is the convection coefficient calculated from the Reynolds number and Nusselt number as described by Gates (1980).

Habitat Manipulation Experiment

To determine the effects of shrub cover on ground squirrel behavior, we constructed artificial shrubs and placed them on a burned sagebrush site. These were designed to provide cover and obstruct the ground squirrels' vision, but had no forage value. They consisted of a chicken wire basket with a diameter of 60 cm and height of 61 cm (approximate volume of 1,782 dm^3) filled with tumbleweed (*Sisymbrium altissimum*). We placed the artificial shrubs on a 36 X 40 m grid at 4-m

intervals, and placed an additional shrub haphazardly within each resulting grid section to break up any visual corridors (200 total shrubs). These shrubs provided the same approximate volume of shrubs found on the OTA sagebrush sites (about 200 dm^3/m^2) when we included a 2-m border around the grid. We then staked out another 36 X 40 m area as a control area. During the same time period, observers watched 2 separate plots and recorded behavior of marked ground squirrels that entered the plots or were within the 2-m border.

Detection Index

We created an index of how far ground squirrels could detect approaching predators from different postures using a pole with wooden forms representing common predators of ground squirrels. We represented weasels and snakes by a 5-cm square resting on the ground, badgers or coyotes by a 50-cm square 20 cm above the ground, and northern harriers by 1-m by 10 cm rectangles 1.5, 2.5, and 4.0 m above the ground. Five points were randomly selected within each of the 6 sites to determine detection distances (random bearings and distances; 2 points off pole 12, 2 off pole 13, 1 off pole 14). From the selected point, we extended a 100-m tape along the same bearing, and 1 person slowly moved the pole with the predator forms along the tape. P. B. Sharpe viewed the pole from 5, 13, and 18 cm above the ground (heights representative of the eye height of a ground squirrel in a standing, sitting, and upright or "picket pin" posture) through holes drilled in a small board. We recorded the maximum distance at which each form was detected from each viewing height. If a detection distance was >200 m (common in burned sagebrush habitats) we categorized this as a distance of 200 m.

Burrow Use

To aid in the interpretation of hole counts as an index of ground squirrel density, we conducted a preliminary study using fluorescent powder. Ground squirrels were captured away from the normal study sites but in similar habitat, marked with hair dye for later recognition, placed into a plastic bag containing fluorescent powder (Radiant Colors, Inc.), covered completely, and released at the point of capture. We recorded the color of powder applied and time of release. After dark on the same day we returned to the areas and followed the resultant fluorescent trails using a Raytech rechargeable UV lamp (Model R5-FLS). We tagged any holes that the powdered ground squirrel entered completely with the ground squirrel identification and a unique consecutive number for that ground squirrel. If the hole had been used previously by another powdered animal, we recorded the original number to indicate sharing of holes.

RESULTS AND DISCUSSION

Activity Budgets.—We recorded 101 hrs of behavioral observations during 270 hrs in the stand. In our analysis, we used only activities that comprised >5% of the mean of observation strings across all animals. We grouped these activities into 4 major categories: "in burrow," "walking," "vigilant," and "foraging." "In burrow" was the proportion of time in which ground squirrels were underground while active. "Walking" was the proportion of time spent in locomotion (minus running, which represented a very small proportion of activity on most sites). "Vigilant" represented the proportion of time in which ground squirrels were alert and was composed of the time spent sitting on haunches (not including time spent sitting and eating), standing in the upright (picket pin) position, standing on all 4 legs with head raised, or standing/sitting in a shrub (not eating or climbing). "Foraging" included eating of any food type.

We calculated an ANOVA with multiple effects for each major activity that indicated significant differences between age classes for time spent in the burrow ($P < 0.0185$) and among sites for all 4 major activities ($P < 0.0396$). No significant differences were found between the sex classes ($P < 0.4687$) for any major activity.

Age.—We compared the proportion of time spent in different activities between age classes using data collected after first juvenile emergence on each site, and found significant differences between juveniles and adults on 3 of 4 sites for at least 1 activity. We could not test for differences on Site 1a because only 1 juvenile was observed. No juveniles were observed during the same period as adults on Site 5b, so we could not make comparisons between age classes. On Site 9b, juveniles spent slightly more time in the burrow, and adults spent more time vigilant on Site 4a and less time walking on Site 10a (Table 1).

Table 1. Percent of time spent in 4 major activities by juvenile and adult Townsend's ground squirrels in the Snake River Birds of Prey Area by site in 1993. Comparisons were made for periods when both were active (post-juvenile emergence).

	Juveniles			Adults			
Activity	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	Prob.>F
Site 1a							
In Burrow	1	11.4	•	4	0.1	0.1	0.0388
Walking	1	0.0	•	4	7.4	2.3	0.1110
Vigilant	1	88.6	•	4	55.6	10.4	0.2299
Foraging	1	0.0	•	4	29.4	6.8	0.0513
Site 4a							
In Burrow	7	11.1	6.5	13	5.6	2.4	0.5453
Walking	7	7.4	1.1	13	7.8	1.6	0.8503
Vigilant	7	15.2	4.2	13	31.4	5.3	0.0493
Foraging	7	54.2	7.7	13	49.0	5.9	0.5839
Site 10a							
In Burrow	7	6.8	3.3	11	8.3	3.3	0.7920
Walking	7	11.7	3.0	11	5.1	1.2	0.0383
Vigilant	7	25.9	3.9	11	31.7	7.1	0.6613
Foraging	7	42.3	4.6	11	43.7	6.3	0.9180
Site 3b							
In Burrow	2	1.4	1.4	4	0.3	0.3	0.4262
Walking	2	1.0	1.0	4	0.7	0.4	0.8794
Vigilant	2	83.5	3.0	4	89.0	5.4	0.4714
Foraging	2	8.3	8.3	4	9.6	5.1	0.8422
Site 9b							
In Burrow	7	4.3	2.1	13	0.7	0.5	0.0351
Walking	7	12.0	2.9	13	7.9	1.7	0.2173
Vigilant	7	31.4	10.3	13	37.3	8.8	0.5754
Foraging	7	41.7	9.1	13	45.4	7.5	0.9051

Habitat.—Because there were no significant differences between males and females and few significant differences between juveniles and adults, we grouped all animals within sites. The ANOVA indicated large site differences in behavior that we investigated using Tukey's Studentized Range Test. As in 1992, sites within habitat types did not differ significantly in the proportion of time spent in each activity (Table 2). There were several significant changes in the activity budgets between 1992 and 1993. Ground squirrels on all sites, except Site 5b, tended to spend less time in the burrow, walking, and foraging, and more time vigilant than in 1992. Site 5b showed the opposite trends. Increases in vigilance were significant on Sites 4a, 10a, and 9b, but time spent walking on Site 4a was significantly less. All other comparisons were not significant at the 0.05 level (Table 3).

There were no significant short-term effects of the experimental tracking conducted in June 1992. Although the amount of vigilance on the tracked OTA sagebrush site (9b) increased significantly between 1992 and 1993, this site did not differ significantly from its control site (5b) in 1993 (Table 3). Site 10a was also tracked in 1992 and showed no significant differences from the control burned sagebrush site (4a) in 1993 (Table 3).

When we combined the data by site type, the results differed slightly from the 1992 season. The burned sagebrush sites did not differ significantly from the OTA sagebrush sites in the proportion of time spent walking, vigilant, or foraging, whereas these 2 site types were similar only in foraging in 1992 (see Van Horne et al. 1992). The mosaic and winterfat sites were similar to each other for all 4 behavior categories and differed significantly from the OTA and burned sagebrush sites in all categories, except time spent in the burrow (Table 4).

We saw similar trends in overall activity in both 1992 and 1993. Foraging rates on burned sagebrush and sagebrush sites in the OTA were significantly higher than those in winterfat and winterfat/sagebrush mosaics during both

Table 2. Major activities of Townsend's ground squirrels in the Snake River Birds of Prey Area, by site, 1993. All squirrels are grouped for each site. Reported values are the percentage of time observed in each activity.

	Activity															
	In Burrow				Walking				Vigilant				Foraging			
Site	*n*	$\bar{x}$	SE		*n*	$\bar{x}$	SE		*n*	$\bar{x}$	SE		*n*	$\bar{x}$	SE	
1a	7	2.0	1.6	A*	7	3.5	1.8	BC	7	73.1	8.7	A	7	17.4	6.2	B
4a	29	7.7	2.0	A	29	5.9	0.8	AB	29	27.5	3.7	B	29	49.2	4.0	A
10a	39	7.3	1.7	A	39	7.4	0.8	A	39	20.5	2.6	B	39	54.4	3.3	A
3b	6	0.7	0.5	A	6	0.8	0.4	C	6	87.2	3.7	A	6	9.2	5.9	B
5b	16	2.7	1.3	A	16	6.0	0.9	AB	16	23.6	5.3	B	16	57.2	5.7	A
9b	32	2.8	0.9	A	32	7.9	1.1	AB	32	32.7	4.6	B	32	46.7	4.6	A

*Tukey's Studentized Range Test. Column values with same letter do not differ significantly at alpha=.05.

Table 3. Observed Townsend's ground squirrel activity patterns in the Snake River Birds of Prey Area, 1992 and 1993.

	1992			1993			
Activity	n	$\bar{x}$	SE	n	$\bar{x}$	SE	Prob. >F
Site 1a							
In Burrow	23	7.0	2.9	7	2.0	1.6	0.4838
Walking	23	4.9	1.0	7	3.5	1.8	0.3711
Vigilant	23	58.2	6.9	7	73.1	8.7	0.3028
Foraging	23	23.4	7.8	7	17.4	6.2	0.6398
Site 4a							
In Burrow	36	13.8	2.8	29	7.7	2.0	0.1317
Walking	36	12.9	1.7	29	5.9	0.8	0.0005
Vigilant	36	7.1	1.1	29	27.5	3.7	0.0001
Foraging	36	55.0	3.1	29	49.2	4.0	0.2768
Site 10a							
In Burrow	32	12.5	3.5	39	7.3	1.7	0.2884
Walking	32	9.8	1.3	39	7.4	0.8	0.2709
Vigilant	32	8.4	1.2	39	20.5	2.6	0.0001
Foraging	32	59.2	4.3	39	54.4	3.3	0.3265
Site 3b							
In Burrow	18	4.8	2.0	6	0.7	0.5	0.3402
Walking	18	3.9	1.2	6	0.8	0.4	0.2738
Vigilant	18	58.1	7.7	6	87.2	3.7	0.0563
Foraging	18	23.0	6.6	6	9.2	3.9	0.3505
Site 5b							
In Burrow	29	2.5	1.1	16	2.7	1.3	0.8543
Walking	29	5.4	1.3	16	6.0	0.9	0.2003
Vigilant	29	32.8	6.3	16	23.6	5.3	0.4259
Foraging	29	51.9	6.3	16	57.2	5.7	0.4203
Site 9b							
In Burrow	29	2.5	1.4	32	2.8	0.9	0.4806
Walking	29	9.0	1.5	32	7.9	1.1	0.8010
Vigilant	29	20.3	5.1	32	32.7	4.6	0.0200
Foraging	29	58.4	4.9	32	46.7	4.6	0.0975

Table 4. Major activities observed in Townsend's ground squirrels in the Snake River Birds of Prey Area, by site type. 1993. All squirrels are grouped for each site type and percent of time spent in each activity is reported.

	Activity															
	In Burrow				Walking				Vigilant				Foraging			
Site Type	*n*	$\bar{x}$	SE		*n*	$\bar{x}$	SE		*n*	$\bar{x}$	SE		*n*	$\bar{x}$	SE	
Burned Sagebrush	68	7.5	1.3	A*	68	6.8	0.6	A	68	23.5	2.2	B	68	52.2	2.2	A
Winterfat/ Sage-brush Mosaic	6	0.7	0.5	AC	6	0.8	0.4	B	6	87.2	3.7	A	6	9.2	3.9	B
OTA Sagebrush	48	2.8	0.8	BC	48	7.3	0.8	A	48	29.7	3.5	B	48	50.2	3.6	A
Winterfat	7	2.0	1.6	AC	7	3.5	1.8	B	7	73.1	8.7	A	7	17.4	6.2	B

*Tukey's Studentized Range Test. Column values with same letter do not differ significantly at alpha=.05.

seasons, whereas levels of vigilance were higher in winterfat and winterfat/sagebrush mosaics (Fig. 2). Overall decreases in foraging between 1992 and 1993 may be explained by increased forage availability during 1993 resulting from high levels of precipitation. Alternatively, such decreases may represent a trade-off with increased vigilance required because of denser vegetation (see Detection Index section below) and an apparent increase in site use by raptors (see Predation section).

Time Above Ground.—We summarized scan samples only for Sites 4a and 10a (burned sagebrush). There were no significant differences among months in 1993 in the estimated amount of time that the ground squirrels remained above ground. This could be real or an artifact of the particularly low sample sizes in April, May, and June. Comparisons across years indicated that animals in May 1992 spent significantly less time above ground (Table 5). Relatively high ambient temperatures in 1992 (see Van Horne et al., this volume) may have reduced the length of time that animals could tolerate ambient conditions.

Environmental Factors.—Fig. 3 shows the combinations of ambient temperature and absorbed radiation that a standing ground squirrel would encounter during a hot, clear day, as calculated from the taxidermic mounts and meteorological equipment, superimposed upon the climate space (see Fig. 1). The shaded region represents all possible combinations of absorbed radiation and ambient temperature that the ground squirrel would encounter (area between minimum and maximum radiation absorbed). The line with open circles represents the actual absorbed radiation calculated from a taxidermic mount between 0900 and 2100 hrs. Measured values generally fall within the predicted values throughout the day, climbing to maximum values when the sun is highest in the sky. There may be a slight delay in the response of the taxidermic mounts to changes in meteorological conditions, but we don't believe this will significantly alter their effectiveness in measuring microclimate conditions in different habitats. Conditions between 1200 and 1900 hrs are above those of slightly active animals near thermal neutrality (Group 2). They are even slightly above maximum tolerance between 1400 and 1600 hrs at a windspeed of 10 cm or less. Thus, conditions between 1200 and 1900 hrs would not be tolerated indefinitely by a squirrel with a body temperature of 37 C, even at high wind speeds. Assuming maximum adjustments to high temperatures, a squirrel would not be able to remain active between 1400 and 1600 hrs unless wind speeds were >100 cm/s. This is consistent with our behavioral observations in which activity tends to diminish during the mid-portion of the day.

We will use diagrams such as the one presented to estimate when environmental conditions are near the extremes that the ground squirrels can tolerate, and to determine whether the ground squirrels modify their behavior (i.e., amount of activity, posturing, habitat use) to reduce the adverse effects of the environment. We are

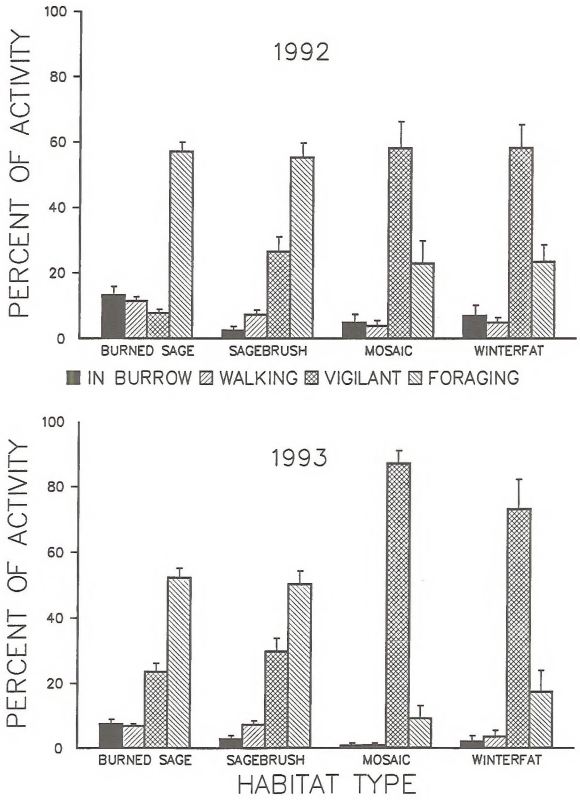

Fig. 2. Summary of percent of time (mean ± 1 SE) spent in 4 major activities by habitat type for Townsend's ground squirrels in the Snake River Birds of Prey Area, 1992-93.

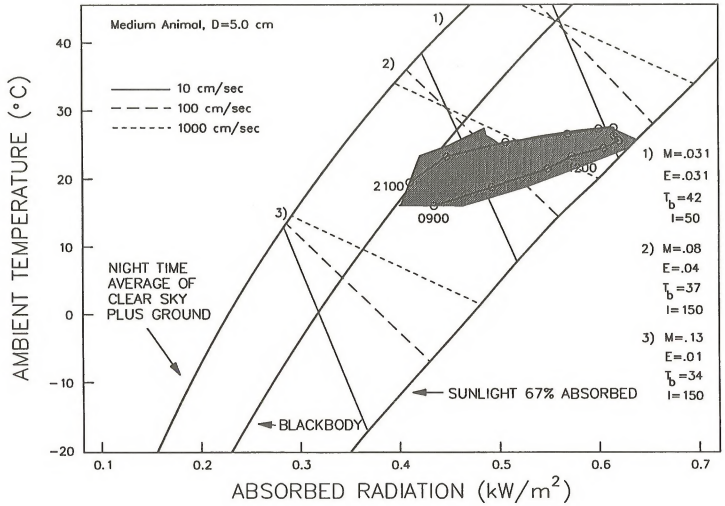

Fig. 3. Climate diagram for medium Townsend's ground squirrel superimposed on the range of combinations of T_a and Q_{abs} occurring on a clear day in May. The shaded area includes all combinations of T_a and Q_{abs} which a standing squirrel in direct sunlight would encounter as predicted from environmental conditions measured with meteorological equipment and applied to a form representative of a squirrel with minimum and maximum proportions of its body receiving direct solar radiation. The solid line with open circles represents the combinations of T_a and Q_{abs} measured with a taxidermic mount in a standing posture. All measurements were taken between 0900 and 2100 hrs on the same day.

Table 5. Percent of time spent above ground by Townsend's ground squirrels in a burned sagebrush habitat during daylight hours as estimated from scan sampling. Both comparisons within year and between years are reported.

	1992				1993				
Month	n	$\bar{x}$	SE		n	$\bar{x}$	SE		Prob.>F
February	6	38.8	8.0	A[a]	19	38.9	4.3	A	0.9845[b]
March	27	32.4	4.0	A	26	37.8	4.8	A	0.3833
April	58	24.5	1.6	A	2	16.5	5.5	A	0.3323
May	32	15.2	1.6	B	7	50.3	9.6	A	0.0001
June	•	•	•	•	2	40.0	25.0	A	•

[a] Tukey's Studentized Range Test. Column values with same letter within year classes do not differ significantly at alpha=0.05.
[b] Comparison of months between years.

especially interested in the role habitat type plays in moderating the effects of environmental factors on ground squirrel behavior. For instance, ground squirrels in an open, burned sagebrush habitat may need to remain in their burrows during extremely hot portions of the day, while those in shrub habitats can remain active in the shade of shrubs, increasing their ability to forage. We are also using the climate space approach to "rate" environmental conditions and to describe the relationship between these ratings and capture rates, as well as raptor activity (Study 2). Results of these analyses will be presented in the 1994 annual report.

Habitat Manipulation Experiment.—Low densities in 1993 prevented us from observing sufficient numbers of ground squirrels to complete this experiment with the design we initially intended to use (cross-over design with a single day of observations before switching plots). If numbers of animals are uniformly low again next season, we will redesign the experiment.

We are primarily concerned with changes in vigilance between experimental and control plots, which different observers sample concurrently. Thus, any observer bias could directly influence results. Prior to attempting the experiment, P. Sharpe and R. Schooley observed individual ground squirrels to determine any biases in observation techniques. Agreement for recorded behavioral observations ranged from 73.5-100% with a mean agreement of vigilance of 89.1 ± 7.03 (± 1 SD). However, overall reported vigilance for the 11 ground squirrels observed was very similar, with 16.1 ± 10.8% and 16.1 ± 10.9% ($\bar{x}$ ± 1 SD) reported by P. Sharpe and R. Schooley, respectively. We report observer variability for each ground squirrel in Table 6. There was no apparent bias towards vigilance for either observer.

Detection Index

Estimated detection distances in this season's index were highly variable, especially for the predator forms at the top of the pole. We combined data for site types to increase sample sizes because we sampled only 5 points per site this season. We dropped a single point on Site 1a for analyses because the transect included a hill, resulting in maximum detection distances of 200 m for several of the predator heights and viewing heights.

Detection distances in the burned sagebrush habitats were significantly greater than in any other habitat type from the sitting and picket pin postures for the 2.5 and 4.0 m predator forms. Mean detection distances in the burned sagebrush were farther than any other habitat type for all other viewing heights and predator heights (except the 0.05 m predator from the standing posture). Significant differences became less consistent, however, as the predator heights neared the bottom of the pole, probably because of small sample sizes and high variability. Fig. 4 shows mean detection distances in different habitat types and indicates that ground squirrels in burned sagebrush habitats can see farther for all postures and predator heights, and those in the mosaic habitat can see the shortest distances. Ground squirrels in a sagebrush habitat have a slight advantage over those in a winterfat habitat

Table 6. Similarity of behavioral observations by R. Schooley and P. Sharpe. Observations of adult squirrels were made on burned sagebursh sites (4a and 10a) in the Snake River Birds of Prey Area, 1993. The percent of time spent vigilant as recorded by the 2 observers and the percent of observations that were identical between the 2 observers are reported.

Sex	No. Obs.[a]	% Vigilant (Schooley)	% Vigilant (Sharpe)	% of Obs. Identical
21 Mar 1993				
?	7	14.3	14.3	85.7
M	54	14.8	18.5	90.7
M	16	43.8	43.8	87.5
F	58	13.8	13.8	96.6
F	12	0.0	0.0	100.0
M	74	16.2	16.2	87.8
M	45	17.7	15.5	93.3
27 Mar 1993				
F	61	11.5	9.8	83.6
F	34	14.7	14.7	73.5
F	58	22.4	22.4	89.7
M	38	7.9	7.9	92.1

[a]Number of recorded behavioral observations made for each individual.

from a standing posture, but lose this advantage when the sitting and picket pin posture are considered.

To gain insight into how ground squirrels use vigilance postures, we analyzed vigilance during standing, sitting, and picket pin postures separately in data taken within 1 month of sampling for the detection index. Ground squirrels in the mosaic and winterfat habitats spend a larger portion of overall vigilance in the more upright postures, or about 80% of total vigilance, and ground squirrels in burned sagebrush and sagebrush habitats spend only about 35% of overall vigilance in these postures (Fig. 5). Upright postures may be less useful in burned sagebrush habitat because our data indicate that the ground squirrels can see farther from the standing posture than ground squirrels in other habitats can see from the picket pin posture. In a sagebrush habitat the increased detection distances are relatively small with increased posture height and cover is abundant, reducing the need for large detection distances. In winterfat and mosaic habitats detection distance may be more important because the vegetation reduces predator visibility but provides little cover, especially in winterfat. Therefore, these ground squirrels should increase their ability to detect predators by either maximizing their detection distances by using more upright postures or increasing overall vigilance. Both phenomena appear to be occurring.

Next season we will use this detection index again and compare results with behavioral observations of vigilance. We will choose more points per site to reduce variation so that differences in detection distances can be more easily distinguished. We will determine the index 2-3 times during the season to see if changes in detection distances result in changes in vigilance levels. We will use only transects running along fairly level ground to minimize confounding factors caused by slopes (i.e., larger detection distances if transect is running uphill, shorter if downhill).

Predation

The occurrence of raptors on our sites during behavioral observations was significantly higher in 1993 as compared to 1992 on 3 of the sites (10a, 3b, 5b) and slightly (but not significantly) higher on the remaining 3 sites (1a, 4a, 9b; Table 7). Only Sites 4a and 5b differed from each other in raptor occurrence in 1993. Estimated mean predation pressure in 1993 ranged from a low of 0.09 raptors/15 min period (0.36 raptors/hr) on Site 1a to a high of 0.4 raptors/15 min period (1.6 raptors/hour) on Site 5b (Table 7). The increased presence of raptors could be due to increased search times necessary to capture ground squirrels because of a decrease in ground squirrel densities from the 1992 levels (see Van Horne et al., this volume).

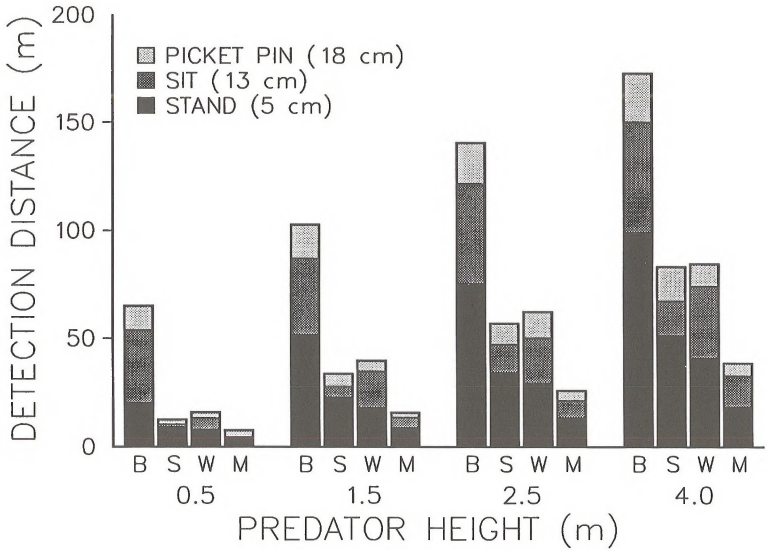

Fig. 4. Estimated mean detection distances of predators of different heights (0.5-4.0 m) by Townsend's ground squirrels from 3 common vigilant postures in 4 habitat types (B=Burned Sagebrush, S=Sagebrush, W=Winterfat, M=Mosaic).

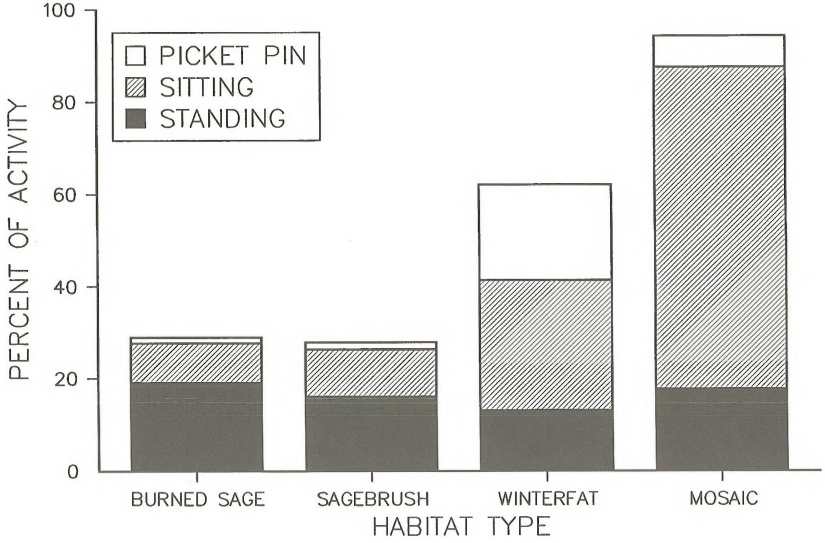

Fig. 5. Mean percent of activity spent in 3 common vigilant postures by Townsend's ground squirrels in the Snake River Birds of Prey Area from 15 April-15 June 1993.

Table 7. Number of raptors observed on Townsend's ground squirrel behavioral sites during 15-min scan samples in the Snake River Birds of Prey Area, 1992-93.

	# of Raptors/15 min.								
	1992				1993				
Site	*n*	$\bar{x}$	SE		*n*	$\bar{x}$	SE		Prob.> F
1a	105	0.08	0.03	A[a]	22	0.09	0.06	AB	0.8472[b]
4a	46	0.04	0.03	A	99	0.15	0.04	A	0.1132
10a	51	0.02	0.02	A	109	0.20	0.04	AB	0.0050
3b	86	0.14	0.05	A	58	0.33	0.08	AB	0.0300
5b	141	0.11	0.03	A	144	0.40	0.07	B	0.0002
9b	139	0.14	0.03	A	151	0.23	0.04	AB	0.0967

[a] Tukey's Studentized Range Test. Column values with same letter within year classes do not differ significantly at alpha=0.05.
[b] Comparison of months between years.

We observed northern harriers (*Circus cyaneus*) more often than the other diurnal raptors above shrub-dominated habitats. The prairie falcon (*Falco mexicanus*) was the most common raptor above the more open burned sagebrush habitats (Table 8).

Burrow Use

We were able to follow the fluorescent trails of 14 ground squirrels in a burned sagebrush habitat and 3 ground squirrels in a winterfat habitat in the preliminary study. We powdered 1 ground squirrel in the burned sagebrush habitat on 2 separate occasions and all others only once. The number of holes we detected ranged from 1-12 (1-10 for a single trail; Table 9). Because we do not know how long the fluorescent powder leaves a trail that is visible with UV light, we do not know what proportion of total hole use during a day this represents. On 1 occasion we recaptured an animal about 1 hr after powdering and saw little powder remaining; we do not know whether the ground squirrel was still leaving a UV visible trail. Ground squirrels probably remove much of the fluorescent powder through grooming, because we often found large patches of dust in or near the burrows that powdered ground squirrels entered upon release. Although the length of the trail which can be followed with

Table 8. Number of raptors detected by species over established 9 ha sites during behavioral observations, February-June 1993. The percentage of total raptors observed at each site is in parentheses.

	Species[a]						
Site	*C. c*	*B. j.*	*B. l*	*A. c.*	*F. m.*	*F. s.*	Unknown
1a	2 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
4a	4 (25%)	0 (0%)	2 (12.5%)	0 (0%)	7 (43.8%)	0 (0%)	3 (18.8%)
10a	6 (31.6%)	0 (0%)	3 (15.8%)	1 (5.3%)	7 (36.8%)	1 (5.3%)	1 (5.3%)
3b	17 (73.9%)	3 (13%)	0 (0%)	0 (0%)	1 (4.3%)	2 (8.7%)	0 (0%)
5b	43 (75.4%)	0 (0%)	0 (0%)	1 (1.8%)	8 (14%)	0 (0%)	5 (8.8%)
9b	26 (74.3%)	2 (5.7%)	0 (0%)	3 (8.6%)	0 (0%)	1 (2.9%)	3 (8.6%)

[a] *C. c.* = *Circus cyaneus* (northern harrier),
B. j. = *Buteo jamaicensis* (red-tailed hawk),
B. l. = *B. lagopus* (rough-legged hawk),
A. c. = *Aquila chrysaetos* (golden eagle),
F. m. = *Falco mexicanus* (prairie falcon),
F. s. = *F. sparverius* (American kestrel).

Table 9. Hole use as determined by fluorescent tracking for squirrels in burned sagebrush and winterfat habitats, Snake River Birds of Prey Area, 1993.

Squirrel #	Days Tracked	Age	Sex	# Holes Used	# Holes Shared With Other Individuals
Burned Sagebrush					
1	1	A	F	6	0
2	2	A	F	12	0
3	1	A	F	5	0
4	1	A	F	2	0
5	1	A	F	7	1
6	1	J	F	8	1
7	1	A	F	4	0
8	1	A	F	2	0
9	1	J	M	10	0
10	1	A	F	2	0
11	1	A	F	1	0
12	1	A	F	5	0
13	1	A	F	2	0
14	1	J	M	3	0
				$\bar{x}$: 4.9 holes/ind.	
Winterfat					
1	1	A	F	1	0
2	1	A	F	2	0
3	1	A	M	1	0
				$\bar{x}$: 1.3 holes/ind.	

a single dusting may be limited, repeated dustings of known animals throughout the next season will produce a more comprehensive record of hole use and a better understanding of total hole use and the amount of sharing of burrows by 2 or more individuals.

PLANS FOR NEXT YEAR

We expect densities to be low again next season because of apparently low reproductive success during the 1993 season. We will continue to monitor any changes in behavior on the 6 sites. We will also measure the detection distance index 2-3 times throughout the season (preferably at the same approximate time as vegetation sampling) to examine changes in detection distances with season and compare results with behavioral observations during the periods bracketing the index determination. We will repeat the cover manipulation experiment to determine the effects of added cover on activity patterns. We will conduct more frequent fluorescent tracking in different habitat types throughout the season to determine patterns of hole use by habitat.

ACKNOWLEDGMENTS

This research was funded by the Bureau of Land Management and the Idaho Army National Guard through BLM Contract YA651-CTO-340032 to Beatrice Van Horne. We thank the 1993 technicians for their cooperation in various aspects of the behavioral portion of the study, and particularly appreciate their hard work in creating and transporting the artificial shrubs and placing readable dye codes on the ground squirrels on the behavioral sites. We also thank Bob Schooley for taking the time to learn the behavioral observation techniques and helping develop and implement the artificial shrub experiment. Finally, we thank all those who spent their free evenings in the field following fluorescent trails, especially Gail Olson and Bob Schooley.

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The Parasite Community of Townsend's Ground Squirrels

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ANNUAL SUMMARY

*In 1993, we continued to collect fecal samples from Townsend's ground squirrels (**Spermophilus townsendii**) from February to June following the protocol established in 1992. We also necropsied 16 squirrels found dead on site. We found that the composition of the eimerian community was the same as in 1992, but that the prevalence of infection averaged across the entire season was significantly higher for 4 of 7 species of eimerian (Fisher's Exact Test (FET), $P < 0.05$) (**Eimeria callospermophili, E. adaensis, E. pseudospermophili, E. morainensis**). The prevalence of all 7 species combined increased from February to June rather than decreased as in 1992. We found 3 of the 4 helminths observed in 1992 and the prevalence of helminths present did not differ significantly from 1992 (FET, $P > 0.05$). Of the animals posted for necropsy, 4 of 16 (25%) had stomach lesions, and 2 were infected with helminths.*

OBJECTIVES

1. To examine the prevalence patterns of parasites in Townsend's ground squirrels with respect to date, squirrel density, sex, age, and habitat.

2. To determine the effects of parasitism on Townsend's ground squirrels in the field on weight, reproduction rates in females and over-dormancy survival.

3. To infer whether biotic (e.g., host physiology) or abiotic factors (e.g., precipitation) are the primary factors influencing the dynamics of the eimerian community in Townsend's ground squirrels.

METHODS

Study sites and methods used in 1993 are the same as described previously (Van Horne et al. 1992) except that fecal samples were obtained from all squirrels captured from mid-March until the end of the trapping season instead of primarily from females, and no squirrels were collected expressly for parasite-related necropsy. All necropsies were performed on trap mortalities and squirrels found dead on site. No blood samples were taken as all smears in 1992 were negative.

RESULTS AND DISCUSSION

Parasite Community Dynamics

The helminth community of Townsend's ground squirrels in 1993 consisted of 3 species (Table 1), and the prevalence (number of infected individuals divided by number of individuals examined, Margolis et al. 1982) of these helminths on all 8 sites combined was not significantly different than in 1992 (Table 1). *Pterygodermatites* sp. (*Rictularia* sp.), although present in 1992, was not detected in 1993. All other helminths were found in both years. Sites 4a and 4b had highest prevalence of tapeworms (*Hymenolepis citelli*) in 1992 (Van Horne et al. 1992) and although estimated density of adults at emergence on these sites declined by >50% from 1992 to 1993, there was no significant change in prevalence of tapeworms (2 of 71, 1993 vs. 14 of 236, 1992). Greatly decreased density is often associated with decreased rates of parasite transmission (Scott 1988). Prevalence of pinworms (*Syphacia citelli*) on site 5a was also unchanged from 1992 to 1993.

Mastophorus sp. (a stomach worm) ova were detected in fecal samples for the first time on site 5b, but prevalence was only 2 of 53. Ova were never detected in 1992, when all recoveries were from necropsies.

The community of eimerians in 1993 consisted of the same species described in 1992 (Wilber et al. 1994), but prevalences averaged across the entire season were significantly higher in 1993 (FET, $P < 0.05$) for 4 of 7 species (Table 1), probably because of better eimerian survival with increased precipitation in 1993 (National Weather Service, Boise, ID). The temporal patterns were also quite different for the 3 most common eimerians and for all 7 species combined.

Table 1. Prevalences (number of individuals infected divided by the number of individuals examined) of endoparasites from Townsend's ground squirrels in 1992 and 1993 at the Snake River Birds of Prey Area, near Boise, Idaho.

Species		1992	(%)	1993	(%)
Helminths					
	Pterygodermatites sp.	6/549	(0.01)	0	
	Hymenolepis citelli	26/549	(0.05)	6/173	(0.03)
	Syphacia citelli	26/549	(0.05)	3/173	(0.02)
	Mastophora sp.	3/549	(0.01)	2/173	(0.01)
Eimeria					
	Eimeria callospermophili	156/605	(0.26)	80/173	(0.46)*
	E. adaensis	162/605	(0.27)	62/173	(0.36)*
	E. morainensis	62/605	(0.10)	28/173	(0.16)*
	E. pseudospermophili	20/605	(0.03)	14/173	(0.08)*
	E. bilamellata	34/605	(0.06)	15/173	(0.09)
	E. beecheyi	23/605	(0.04)	9/173	(0.05)
	E. lateralis	12/605	(0.02)	2/173	(0.01)

* Indicates values that are significantly higher ($P < 0.05$) using Fisher's Exact Test.

In 1992, the eimerian community showed a steep and significant decline from February to June that we attributed to drought and not to host immune response (Wilber et al. 1994). In 1993, a wetter year, prevalences in February were equal to the June 1992 levels and then increased rapidly until early April (Fig. 1). This increase is not significant using a linear regression model, but is the converse of the trend observed in 1992. These results are consistent with our hypothesis that the eimerian community is controlled by abiotic factors such as rainfall rather than by host physiology.

The 3 eimerians most common in 1992 were also the most common in 1993, (*E. callospermophili*, *E. morainensis*, and *E. adaensis*), but their prevalences were more stable in relationship to one another than they were in 1992 (Fig. 2; see Van Horne et al. 1992, Fig. 13). This is consistent with the results of Seville (1992) who found that the prevalences for the 6 species of eimerians in *Spermophilus elegans* were consistent over time.

The prevalence of infection with eimerians in adult squirrels was higher than in juveniles (Table 1). These differences were not significant in 1993, whereas they were in 1992. These data continue to support the hypothesis that sterile acquired immunity is not important to regulating the eimerian community, but suggest that differences between years can be significant. There were differences between sexes (FET, $P < 0.05$).

Twenty-three percent (16 of 68) of the individuals captured more than once were infected with the same species of eimerian on 2 or more dates separated by at least 15 days. Because the patent period for the ground squirrel eimerians is usually <10 days (unpubl. data), infections observed 15 days or more apart were considered independent infections. Unfortunately, expected rates of reinfection are difficult to calculate because probabilities of infection are time-dependent and because squirrels were captured and recaptured at different times and at different intervals.

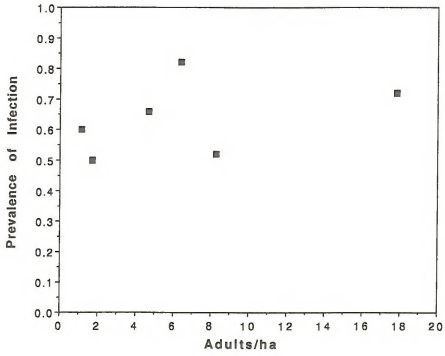

Fig. 1. Prevalence of all *Eimeria* species combined for all captures of Townsend's ground squirrels (n = 173, 333 captures) at the Snake River birds of Prey area near Boise, Idaho by day of year.

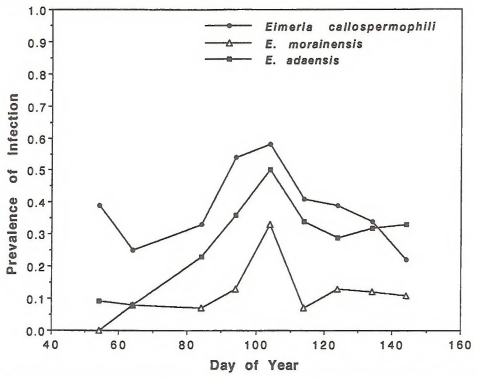

Fig. 2. Prevalence of the 3 most common *Eimeria* species by day of year in 173 Townsend's ground squirrels captured 333 times. Data are pooled into 10-day intervals and all duplicate records are summed, thus each data point is made up of unique individuals.

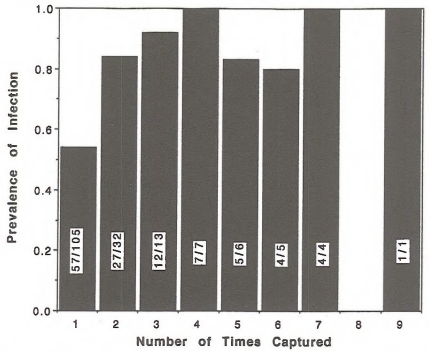

Fig. 3. The relationship between the number of times an individual Townsend's ground squirrel (*Spermophilus townsendii*) is captured and the likelihood of observing an eimerian infection in 1993.

The probability of observing an eimerian infection in a given individual increases the more often a squirrel is captured (Fig. 3). Thus, the probability that a given squirrel will be infected with eimerians once during the active season is nearly 100%. This is similar to the pattern exhibited by measles infections in children in developing countries (Anderson and May 1991).

Ulcers

Stomach lesions were observed in 4 of 16 squirrels found dead on site and then necropsied. Histological exam of these ulcers showed that they were shallow and did not perforate the stomach lining. Ulcers are more common in individuals in poor condition, but are probably a result of poor health rather than a cause of poor health. Ulcers are common in zoo animals (J. Hnida, University of New Mexico, pers. commun.), but no similar phenomenon has been reported for free-living vertebrates.

Effects of Parasitism on Squirrels

Although Price (1990) contended that all parasites incur measurable cost to the host, we have not been able to demonstrate any effects of parasitism by coccidia or helminths on free-living Townsend's ground squirrels. In 1992, during the drought that severely reduced the squirrel population, we saw no relationship between parasitism and weight or reproduction in females. When we examined prevalence of eimerian infection for those animals captured in both 1992 and 1993, we found that prevalence of infection in these animals in 1992, prior to hibernation, was 20% higher than expected. Perhaps the animals that survived the drought and were recaptured were in better condition than those not recaptured and thus were better hosts for eimerians. Prevalence of infection in these individuals in 1993 was no different than 1993 population. We did not analyze incidence of helminth infection in recaptured individuals because prevalence of helminths in general is so low.

Factors Influencing the Eimerian Community

Abiotic factors seem to be the primary influence on prevalence of eimerians in Townsend's ground squirrels. In 1992, host density was relatively unimportant until densities fell below 1

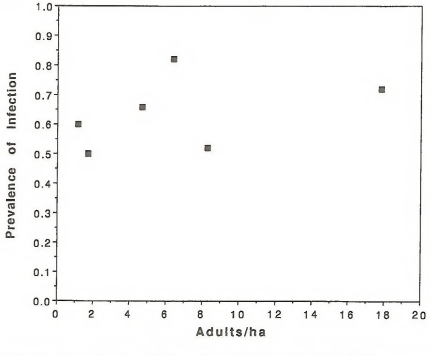

Fig. 4. The relationship between Townsend's ground squirrel density (adults/ha) and prevalence of Eimeria in 1992. Information from animals captured repeatedly was summed into a single record so that prevalence is not a reflection of total captures, but of unique individuals on each site.

adult/ha (Van Horne et al. 1992). This threshold density of 1 adult/ha may be lower in years in which eimerian survival in the environment is high such as 1993. In 1993, we found no significant relationship between prevalence of infection and density using linear regression (Fig. 4).

Age structure may also be important. Our lab experiments suggest that juveniles with little previous exposure to eimerians carry infections over the torpid period better than previously infected adults. If this is true, then yearlings may be an important source of initial infections of eimerians soon after emergence. The earliest estimate of prevalence in February of 1993, when virtually no yearlings were present, was only 11%. Unfortunately, this sample size is too small (9 individuals) to be considered statistically robust. Nevertheless, prevalences quickly increased (Fig. 2), suggesting that if yearlings are important, their significance is quickly masked by transmission patterns within the remainder of the population. This may be especially true in years with good eimerian survival. Yearlings may be more important to the eimerian community in years when abiotic factors (low precipitation, high temperatures) severely stress the eimerians.

Squirrel habitat may be correlated with prevalence of eimerians. Although shrub sites that have more shade would appear to be more conducive to eimerian survival than open sites, shrub sites had lower prevalences of infections than open sites in 1992 (0.35 vs. 0.53, $P < 0.001$). However, even though the percentage difference was about the same in 1993, there was no significant difference in 1993 because of decreased sample size (605 in 1992 vs. 173 in 1993).

PLANS FOR NEXT YEAR

We will continue to collect feces from squirrels on the parasite study locations to obtain a more complete picture of the dynamics in the eimerian community and how these are intertwined with the patterns of the squirrel community.

ACKNOWLEDGMENTS

I would like to thank all the Study 4 technicians at the Kuna field site who collected the fecal samples, and all other Study 4 members who took time to provide data to me. This work was funded by the BLM Contract YA-651-CTO-340032 to Beatrice Van Horne, and the Graduate Research Allocations Committee, the Student Research Allocations Committee, and the Vice Presidents Student Research Fund at UNM to Patricia G. Wilber.

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Dispersal Movements of Juvenile Townsend's Ground Squirrels

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ANNUAL SUMMARY

*Beginning in late April, we radio-collared and tracked 28 (16 males, 12 females) juvenile Townsend's ground squirrels (**Spermophilus townsendii**) on 2 sites of different habitat types within the Orchard Training Area (OTA) on the Snake River Birds of Prey Area (SRBOPA). Although we had numerous technical difficulties due to poor juvenile production (resulting in small sample sizes) and slippage of radio-collars (resulting in ambiguity of fates of a number of animals), we were able to positively identify dispersal of 6 ground squirrels, all males. These dispersed an average of 447 m (range 157-1,005 m), always to a habitat type similar to their natal habitat.*

OBJECTIVES

1. To radio-collar 15 juvenile ground squirrels in each of 2 habitat types (shrub and open grassland) and determine their locations daily beginning in mid-April and ending with immergence in late June 1993.

2. To track dispersing juveniles and determine the end points of dispersal movements.

3. To follow dispersing individuals, whenever possible, and map the actual path of movement with respect to habitat and topographic features.

4. To compare sex-specific movements of radio-collared ground squirrels.

5. To determine fates (over-winter survival) of radio-collared animals by target trapping in 1994.

METHODS

Study sites

We chose 2 BLM\IDARNG Study 4 study sites for this study that had relatively high ground squirrel densities, were representative of different source habitat types, and had other habitat types nearby to serve as potential dispersal destinations; site 9b (a sage [*Artemisia tridentata*] site located within the OTA near the quarry north of Christmas Mountain), and Site 10b (a burned sage site within the OTA located near the northwestern boundary). Although both sites were tracked experimentally in 1992, the treatment apparently had little impact on ground squirrel populations (see Van Horne et al., this volume). Originally, Sites 3b (a sage-winterfat [*Ceratoides lanata*] mosaic site located outside the OTA near Coyote Butte) and 2b (a sage site also located outside the OTA near Coyote Butte) were to have been used as shrub sites for this study; however,

early trapping results indicated that sample sizes would not be sufficient to conduct the study on these sites. This change of study sites created a number of problems, the greatest of which were the increase in travel time between sites (reducing the number of times per day sites could be visited to 1), and an increase in difficulty of tracking radio signals because of more interference from nearby IDARNG activities as well as the presence of large amounts of volcanic rock, which greatly reduced signal range.

Collaring

Beginning in mid-April, radio-transmitters were placed on all eligible (defined below) juvenile ground squirrels captured on the 2 study sites. These were attached to a collar package with weights ranging from 4.64 to 4.89 g. This was the smallest available package with sufficient duration (4-6 weeks, 30 days guaranteed by the manufacturer: Advanced Telemetry Systems, Isanti, MN) and range (up to 400 m for animals below ground and at least 600 m above ground; Olson 1992) to conduct this study. Study 4 personnel trapped the animals during normal trapping efforts, although these sites were trapped somewhat more frequently than other Study 4 sites to supplement radio-telemetry efforts. A combination of ground squirrel mass and capture history was used to determine whether captured juveniles were eligible for collaring. A minimum animal mass of 90 g was set so that transmitter packages would be roughly $\leq$5% of body mass. Initially, we did not collar first captures as we thought that adding collaring procedures to injection with PIT tags would be too stressful for a juvenile ground squirrel to handle at 1 time. However, because recaptures of juvenile squirrels were so rare, we began to collar newly captured squirrels if they appeared to be unaffected by PIT-tagging, especially if they weighed $\geq$105 g. Larger juveniles (>120 g) were generally collared only if previously captured at lower weights to minimize the possibility of collaring ground squirrels that had recently immigrated onto study grids.

Collaring began as soon as eligible ground squirrels were caught (24 April for Site 10B, 1 May for Site 9B), and continued as long as we thought uncollared juveniles that met our criteria remained. Because the guaranteed duration time of batteries powering transmitters was only 30 days, any animals still alive were re-trapped by target trapping 30 days after initial collaring and their transmitters replaced with new ones. This tactic was also used earlier (prior to 30 days) if the signal started to fail prematurely.

Tracking

As soon as any ground squirrels were collared, their locations were recorded daily. At the minimum, animals were located as either on or off the trapping grids, and all animals off of the grids were located exactly by "walking them up". Generally, however, animals within the study grid were "walked up" each day as well. Often ground squirrels were found to be above ground, or would take temporary refuge in a hole; in those situations no exact location was recorded although a notation of a visual sighting was made. Otherwise, exact locations (burrows) of ground squirrels were marked, uniquely numbered, and measured to a known reference point, such as a pole within the study grids. Locations of reference points located well off of our study grids were determined using the Global Positioning System (GPS) with a 2-5 m circular error probable (50% of points are within that radius).

Tracking of each collared animal continued until 1 of several possible fates was determined: animal was found dead, collar was found with no animal, signal was tracked to the same location for several consecutive days (at least 5) regardless of what time of day locations were taken, signal was lost completely and not found after extensive searching, or the animal survived to estivation.

RESULTS AND DISCUSSION

Collaring

We collared 28 juvenile ground squirrels with radio-transmitters in 1993: 8 males, 9 females on Site 9b, and 8 males, 3 females on Site 10b. Generally, ground squirrels tolerated collaring rather well, even when it was done during the same session as PIT-tagging. However, many of them hampered our efforts by apparently expanding their necks while being fitted, leading to a number of slipped collars. Unfortunately, this problem was discovered after many radios had been put out, and captures of eligible ground squirrels were few after that time. (See discussion on ultimate fates, below). We replaced 5 initial transmitters by target trapping, which was always successful.

Tracking

We recorded 860 attempted locations (radio checks) between 24 April and 30 June, found signals 797 times, and tracked animals to exact locations 526 times. On a per animal basis we averaged 30.7 checks, 28.5 finds, and 18.8 locations. We marked a mean of 6.4 unique locations per individual (180 total), with a range of 0-24. Although most of these unique locations were holes (a few were exact locations of signals underground which we could not associate with any identifiable hole), this statistic is not a good indicator of how many holes are actually used per individual ground squirrel because we did not record holes used as temporary refuges in response to our approach. However, because we do know that each of these holes was used by an individual ground squirrel, it may be considered a minimum number of holes used per juvenile.

Ultimate fates of collared animals are given in Table 1. The most dramatic (and discouraging) statistic in Table 1 is the number of animals whose fates were unknown (18). Most of these (12) were transmitters that could be traced to a single location underground, but we did not know whether the animal lost the collar while underground and remained alive, or died underground while still retaining the collar. All of these were located within or immediately adjacent to the study grids, so no attempt was made to dig them up so as not to disturb the trapping study. If the animal had carried the collar <5 days we inferred that it had slipped its collar; otherwise we inferred that it had died. The same criteria were used to assess fates of animals when the collar was found laying on the ground. The 1 case where a lost signal was categorized as 'probably died' was when an animal that had been followed for several weeks and had a strong radio signal disappeared late in the season. This animal had already dispersed from the trapping grid, and a widespread search of the area failed to detect a signal. Given these interpretations as incorporated in Table 1, we summarize that 5 animals survived, 12 died or probably died, and 11 had unknown and uninferable fates.

Altogether, 6 juveniles were classified as dispersers, all of which were males. Two of these were known to have survived to estivation, 3 were known to have died, and 1 was probably dead. Of the 5 animals that survived to estivation, 2 were known not to have dispersed (a male and a female), and 1 probably did not disperse (a male). Of the animals that died or probably died on the study grids, 3 (2 females and 1 male) were thought to be non-dispersers because the length of time they remained within the grid area was beyond the period when dispersal apparently took place. In summary, then, 100% of 6 dispersers were male, and 67% of the 9 males which could be classified dispersed. Because of small sample sizes, it would be unwise to draw conclusions about dispersal rates or the survival rates of dispersers (which did not appear to be different than for non-dispersers). However, some observations of characteristics of dispersers proved to be interesting.

Table 1. Survival of all juvenile ground squirrels radio collared on the Snake River Birds of Prey Area, 1993 (sites combined, $n = 28$).

Ultimate Fate	Number of Animals
Survived to estivation	5
Died (Known)	5
Unknown Fate	18
Lost signal	2
Probably died	1
Unknown	1
Stationary signal	12
Probably collar slipped	6
Probably died	4
Unknown	2
Collar found	4
Probably slipped	2
Probably died	2

The 6 dispersers travelled distances of 157, 204, 332, 383, 601, and 1,005 m, for an average of 447 m. Dispersal distances were taken from either known natal burrows (4 cases), the suspected natal burrow (1 case), or the trap location at which the animal was collared (1 case) to the last known hole used by the animal. Two pairs of dispersers were known to be litter mates, and dispersed independently of each other, leaving at different times, travelling in different directions, and even behaving differently during dispersal. (For instance, 1 eventual disperser made lengthy exploratory movements in at least 2 different directions prior to dispersing permanently over 1 day, while his litter mate made small consecutive movements in a single direction over several days before remaining in 1 area). All dispersers ended up in habitat similar to that in which they were born, although 2 (1 starting in sage, the other in burn) relocated to areas where they could have chosen either habitat type. It was not possible to actually track animals in transit while dispersing, but it appeared that 1 animal initially followed a narrow cowpath, and then an old streambed. No animal was thought to have used a road for a travel lane, although at least 1 animal crossed a road, and 2 others must have encountered one.

Small sample sizes, especially on the burn site, preclude even qualitative comparisons between site types.

PLANS FOR NEXT YEAR

The final objective of this study is to determine if the animals known to have estivated did indeed survive over-winter, so we (in conjunction with Study 4 personnel), will make every effort to establish their fates. Although results of this study were somewhat disappointing in terms of number of animals whose fates were not determined, we hope that funding will be approved so that we can repeat the study in 1994. We have several reasons to be optimistic about improved results: (1) we are now fully aware of the potential for collars to be slipped and can work with the manufacturer to rectify this problem; (2) because 1994 is the last year of the trapping study we can dig up stationary collars within the study site (after trapping has been concluded) and directly determine the fates of animals; (3) 1993 was an extremely poor production year for ground squirrels. Although we expect very low adult densities in 1994, juvenile production *per capita* should be higher if conditions are more "average".

ACKNOWLEDGMENTS

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Olson, G.S. 1992. Feasibility of using radio-telemetry to study dispersal movements of Townsend's ground squirrels on the Snake River Birds of Prey Area (SRBOPA). Pages 406 - 408 *in* K. Steenhof, ed. Snake River Birds of Prey Area Res. and Monitoring, Annu. Rep. U.S. Dep. Inter. Bur. Land Manage., Boise, Id.

Habitat Classification and the Ability of Habitats to Support Populations of Townsend's Ground Squirrels and Black-tailed Jackrabbits

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ANNUAL SUMMARY

*We sampled vegetation at 165 points, including 54 points established within the ISA but south of the Snake River. When comparing vegetation sampled at sites from 1991 through 1993, sample year was the strongest influence on species richness (S), diversity (H), and ground cover of vegetation species. Within low density sagebrush (**Artemisia tridentata**) sites, the high category of military incidence had significantly lower ($P = 0.08$) species richness (6.18 ± 0.40, $\bar{x} \pm$ S.E., $n = 4$) and lower percent cover of exotic plants (2.15 ± 0.62, $n = 4$) when compared to sites with low military tracking incidence ($S = 7.00 \pm 1.35$, % exotics = 10.25 ± 4.01; $n = 17$). Low density grassland sites with a high incidence of livestock had significantly higher percent cover of exotic plants when compared to sites with low incidence of livestock (high: 9.26 ± 0.81, $n = 97$; low: 5.69 ± 1.17, $n = 24$).*

*We sampled numbers of Townsend's ground squirrel (**Spermophilus townsendii**) burrows at random sites within the ISA and OTA from 17 May through 17 June. Total number of burrows counted on 47 historical transects averaged 216.3 ± 23.0 burrows/ha ($\bar{x} \pm$ S.E.) and were higher than total number of burrows counted in 1992 (196.3 ± 21.8 burrows/ha). Total number of burrows counted on 183 randomly located transects averaged 189.0 ± 9.3 compared to 262.0 ± 13.6 total burrows/ha counted for randomly established transects in 1992 ($n = 166$) and 169.0 ± 15.8 in 1991 ($n = 115$). A resource selection model predicted 2 probability of occupancy states for a given ground cover of native grasses.*

*Winter densities of black-tailed jackrabbits (**Lepus californicus**) along all spotlight transect routes (660.32 km) were 0.07 jackrabbits/ha (0.06-0.08, 95% C.I.) compared to 0.15 jackrabbits/ha during winter 1991-92. Spring jackrabbit densities declined in 1993 ($D = 0.069$/ha, 0.056-0.085) compared to 1992 ($D = 0.272$/ha, 0.2411-0.308) and 1991 ($D = 0.233$/ha, 0.204-0.267). We also observed 3 Nuttall's cottontail rabbits (**Sylvilagus nuttallii**), 531 kangaroo rats (**Dipodomys ordii and D. microps**), and 15 mice and voles (including **Lemmiscus curtatus, Microtus** sp., **Onychomys leucogaster, Perognathus parvus, Peromyscus maniculatus,** and **Reithrodontomys megalotis**) on spring spotlight transects. On winter transects, we counted 4 Nuttall's cottontail rabbits, 1 pygmy rabbit (**Brachylagus idahoensis**), 92 kangaroo rats, and 1 deer mouse.*

OBJECTIVES

1. To assess influence of military activities and livestock use on vegetation.
2. To determine the influence of military activities and livestock use on abundance of Townsend's ground squirrels and black-tailed jackrabbits.
3. To determine habitat correlates of Townsend's ground squirrel and black-tailed jackrabbit abundance.
4. To monitor trends in distribution and abundance of Townsend's ground squirrels and black-tailed jackrabbits.
5. To establish permanent transects that will be resampled at specified intervals for long-term monitoring of vegetation.

INTRODUCTION

Abundant populations of Townsend's ground squirrels and black-tailed jackrabbits are needed to maintain one of the world's highest densities of nesting raptors in the Snake River Birds of Prey Area (SRBOPA) (U.S. Dep. Inter. 1979, Steenhof and Kochert 1988). In recent years, public concerns were raised that intensive grazing (Yensen 1980), extensive wildfires (Kochert and Pellant 1986), and long-term military activities in the Orchard Training Area (OTA) had influenced habitat and prey communities in the SRBOPA. The purpose of Study 5 of the Bureau of Land Management/Idaho Army National Guard Research Project (BLM/IDARNG) is to evaluate the influence of these activities and provide an accurate description and spatial delineation of habitats and prey communities within the SRBOPA.

METHODS

Townsend's Ground Squirrels and Habitats

Selection of Random Sampling Locations.—We sampled habitats and prey within the Integration Study Area (ISA) of the SRBOPA, including the OTA. An initial sample of 1,000 sites within the ISA was randomly selected in 1990 (Knick 1991); number of sites was apportioned between the ISA (excluding the OTA) and the OTA based on their relative areas. In 1993, we sampled vegetation at 165 points, including 54 points established within the ISA but south of the Snake River. All sites were marked in the field by a single metal fence post, and each site's position was recorded by a Global Positioning System for future studies of long-term changes (e.g., Anderson and Holte 1981, Turner 1990).

Townsend's Ground Squirrels.—We sampled numbers of Townsend's ground squirrel burrows at random sites within the ISA and OTA from 17 May through 17 June. The 1-month sampling period was shorter than previous years and was designed to minimize variability in weather, burrow dynamics, and squirrel behavior. Comparisons of burrow numbers on transects sampled over longer intervals more likely reflect variability caused by weather and burrow degradation after squirrel emergence rather than actual differences in the index to a population size (Knick 1992).

An observer recorded all ground squirrel and badger (*Taxidea taxus*) burrows in 5 x 400-m strip transects (Fig. 1) at sites also sampled for vegetation. Burrows were sampled on 47 transects established in 1982 (Peterson and Yensen 1986, Yensen et al. 1992), 134 transects established by Study 5 in 1991 and 1992 (Knick 1991, Knick 1992), and 49 transects sampled for vegetation in 1993.

Criteria to distinguish active burrows from inactive included absence of wind-blown debris or spider webs, presence of claw marks or feces at the burrow, presence of trails emanating from the burrow, observation of squirrels, or absence of plant roots from burrow ceiling (Peterson and Yensen 1986, Yensen et al. 1992). We defined "active burrows" as burrows in use by ground squirrels strictly at the time of sampling, rather than the looser criteria used in previous years that defined active to include any use during the entire season (Knick 1991). We also assigned a high or low certainty factor to active/inactive status. Thus, each burrow was classified into 1 of 4 categories: active-certain, active-uncertain, inactive-uncertain, and inactive-certain.

Calibration Transects for Burrow Counts.—We repeated burrow counts at calibration transects during each week of the sampling period to establish variations in counts due to factors other than squirrel behavior. Calibration transects were established in 1992 (Knick 1992). The sample unit was the 5x400-m transect, and we used 5 transects each in sagebrush, winterfat (*Ceratoides*

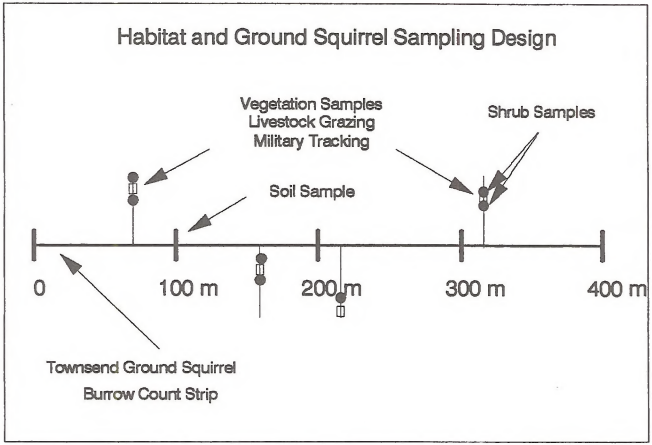

Fig. 1. Design for sampling habitat and Townsend's ground squirrel burrows at randomly located sites.

lanata), sagebrush-winterfat mosaic, a native perennial grassland of Sandberg's bluegrass (*Poa secunda*) and bottlebrush squirreltail (*Sitanion hystrix*), and a grassland dominated by cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola iberica*).

Vegetation and Soils

Vegetation.—Vegetation, and military and grazing information were sampled on ≥4 50-m transects perpendicular to the center line of the 400-m strip transect (Fig. 1, Table 1). At least 1 50-m transect was randomly located within each 100-m segment (Fig. 1). Therefore, each site effectively sampled a 100 x 400-m area (4 ha).

We sampled vegetation (species composition, frequency, canopy cover, % bare ground) by point intercept (Floyd and Anderson 1982) from 1 5-m section at randomly determined points on each 50-m transect (Fig. 1). The sample unit consisted of a 5-m section. The number of sample units with single 5-m sections needed to determine vegetation characteristics was assessed in the field by calculating a running mean (Grieg-Smith 1983) of the 4 most abundant categories and ranged from 7-11. Additional transects needed to obtain a stabilized mean were added at randomly selected points along the entire 400-m burrow count transect. Scientific and common names of all plants sampled by Study 5 are listed in Appendix A.

When shrubs were present, shrub density, mean shrub height, mean shrub height from ground to canopy, and presence/absence of canopy was determined from 20-m^2 (2.52-m radius) plots (Asherin 1973). Number of shrubs needed for sampling was calculated from a running mean. Shrub plots were established at each end of the 5-m sections for vegetation sampling by point frame (Fig. 1).

Species richness (S, number of species present) and species diversity (H) were determined from total species composition at a sampling site. The diversity index was $H = 1/\Sigma p_i^2$ where p_i was the proportion of the ith species in the total sample (N_i/N) (Hill 1973, May 1981). This index equaled 1 when a single species dominated the sample; higher values resulted from increasing number of species and evenness of distribution.

Habitat class was assigned to each transect based on the classification scheme developed from all vegetation transects sampled from 1991 through 1993 (Knick et al. 1992, this volume). I grouped

Table 1. Variables measured on strip transects for counting burrows of Townsend's ground squirrels. Food items will be determined from analysis of fecal pellets (Van Horne et al., this volume).

Variable	Data Type
No. TGS Burrows	Continuous
No. Badger Burrows	Continuous
Plant Species	Diversity index; Species richness
Food Items	Percent
Plant Species Cover	Percent
Canopy Cover	Percent
Bare Ground	Percent
Shrub Height	Continuous
Height to Canopy	Continuous
Soils	Continuous
% Clay	
% Sand	
% Silt	
% Nitrates	
% Organic Content	
Soil Depth	Continuous
No. cow fecal pats	Continuous, categorical, or binomial
No. sheep feces	Continuous, categorical, or binomial
No. Livestock Tracks	Percent Cover
Pocket gopher mound	Percent Cover
No. tank tracks	Percent Cover, categorical, or binomial

categories for shrub (all Class 1A, 1B), grass (all Class 2A and 2B), and disturbed (all Class 1D) sites in the analyses.

Soils.—Soil samples were collected at the 100-m point along the burrow count transect (Fig. 1). At each point, we collected samples from the surface and at 1-m depth to determine soil texture. Soil samples were sent to the University of Idaho for analysis of soil texture (percent sand, clay, and silt), percent organic matter, and percent nitrates.

I used 2 statistical approaches to determine soil and vegetation relationships. With canonical correspondence analysis (CANOCO, ter Braak 1988), I examined direct relationships between vegetation (species variables) and soil (environmental variables). Canonical correspondence analysis is a multivariate direct gradient approach for analysis of community variation relative to the environment (ter Braak 1986). In canonical correspondence analysis, the ordination axes of the set of species data (representing variation in the vegetation community structure) are constrained to be linear combinations of the environmental variables (soil variables), and species are assumed to have a unimodal response to the environmental gradients (ter Braak and Prentice 1988). In the second statistical analysis, the ability of soils to predict habitat type was tested by a quadratic discriminant function (PROC DISCRIM, SAS Statistical Institute 1988) with habitat type as the classification variable and soil variables as predictor variables. Soils and vegetation sampled in 1991 (n = 80) and 1992 (n = 92) were used in these analyses.

Military Use and Vegetation.—Tracking intensity was determined by summing categorical estimates (presence = 1; absence = 0) of military tracks along each 100-m segment of the 5-m wide transect line (Fig. 1) and provided scores for low (0-2) and high (3-4) tracking incidence. I tested the hypothesis that percent cover of vegetation, species richness, and diversity were independent of tracking intensity with a 2-way analysis of variance (tracking, year, tracking*year) (Proc GLM, SAS Statistical Institute 1988) controlled for habitat type.

Percent cover of tracks also was determined from point frame counts. A second 2-way analysis of variance was used to test for differences in tracking within habitat types. Habitat and year were main factors and habitat*year was the interaction factor.

Significance was determined from the Type III sum of squares in the full interaction models. All vegetation transects in the OTA sampled from 1991 through 1993 were used in these analyses. Results provide correlative inference, but not cause and effect.

Livestock Use and Vegetation.—At each burrow count transect, a sum of categorical estimates (presence = 1; absence = 0) of cattle and sheep use was obtained along each 100-m segment (Fig. 1) from presence of fecal material, or tracks and provided scores for low (0-2) and high (3-4) livestock incidence. I tested the hypothesis that percent cover of vegetation, species richness, and diversity were independent of livestock presence with a 2-way analysis of variance (livestock, year, and livestock*year) controlled for habitat type.

Percent cover of livestock litter also was determined from point frame counts. A 3-way analysis of variance was used to test for differences in livestock litter by habitat, year, and area (OTA vs. ISA). All 2-way interactions also were included. Sample sizes were too small for interpretation of the 3-way interaction (area*habitat*year) model. If grazing were uniformly distributed among habitat, year, and area factors, then livestock could be considered a constant at a gross scale.

Significance was determined from the Type III sum of squares in the full interaction models. All vegetation transects sampled from 1991 through 1993 were used in this analysis.

Military and Livestock as Environmental Variables.—I used percent ground cover of military tracking and livestock litter as environmental variables in a canonical correspondence analysis (ter Braak 1986) with vegetation species. My objective was to determine relationships between the ordination of plant species and military or livestock gradients.

Statistical Analysis of Ground Squirrels and Habitats

I used logistic regression to develop resource selection models for Townsend's ground squirrels from samples of used and available habitats (Manly et al. 1993). The entire study area for habitats and use was sampled at the population level, without identification of individuals (Sampling Design I, Protocol A; Manly et al. 1993). Assumptions implicit in any study to determine

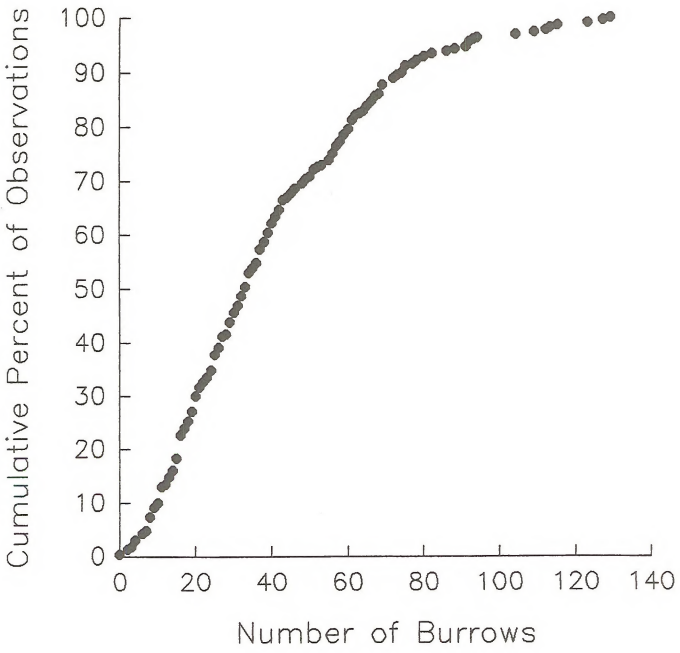

Fig. 2. Cumulative percent of the histogram of burrow count numbers for 230 strip transects sampled in 1993 in the OTA and ISA. The upper 25% of the counts (>60) was used as the high category of population index.

resource selection functions include stable distributions of measured variables and resource selection probabilities, correct identification of available and used populations, independent and random sampling, and that organisms have free and equal access to all resource units (Manly et al. 1993).

I used the high category of burrow numbers (>60 burrows/transect) for analysis with habitats to determine resource characteristics of regions with presumably dense populations of ground squirrels. Separation of categories was determined from visual inspection for breaks in cumulative frequency of the histogram of burrow number at transects (Fig. 2) for 1993 samples. I made the general assumption that 25% of the sites with the highest burrow counts (>60 burrows) also represented sites with abundant ground squirrel numbers more than sites with low numbers of burrows. Numbers of burrows were not strongly correlated with population size (Van Horne et al. 1991, 1992) and were further confounded by observer bias and length of sample period (Knick 1990, 1991, 1992).

The set of available habitats consisted of all sites sampled for vegetation in 1993 north of the Snake River (n = 111). Habitat variables from vegetation surveys were percent cover of individual species, grass, shrub, disturbance groups, and species richness and diversity.

I also included large-scale landscape features as potential factors in resource selection models predicting presence of Townsend's ground squirrels. I used remote sensing data from Landsat Thematic Mapper satellite images to describe landscape characteristics within a 1-km radius around each site. Image resolution was 25 m, and each survey site contained 5,023 pixels. Two images, taken on 9 September 1990 and 30 March 1991, were used to determine an abstract description of habitat. Each pixel had a value between 1 and 255 potential shades in each of 7 spectral bands (6 reflective, 1 thermal) in each image. Therefore, each pixel was described by 14 spectral variables.

I used principal components analysis (PCA) to reduce 14 spectral variables and used the first component axis score as a habitat variable. To standardize variance among all sites, I scored pixels at each site using coefficients derived from a PCA of 10,000 random points within the study area. The first PCA component accounted for 62% of variation within the spectral data.

I determined the relationship between scores on PCA axis 1 and habitats by translating pixels into habitat classes using spectral data (Knick et al., this volume). PCA axis 1 represented a shrub-grass-disturbance gradient (Fig. 3) but was not related to cover of any single plant species (Knick et al. 1992).

I determined landscape heterogeneity from an omnidirectional variogram (Rossi et al. 1992). The variogram calculates the semivariance, $\gamma(h)$, an estimate of spatial predictability, from the difference in value x for all possible point (z) combinations at a given distance:

$$\hat{\gamma}(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2$$

where h is the distance between points, and N(h) is the number of pairs of points at distance h. I used 25-m increments in distance between point combinations because of the resolution of satellite imagery. Because points at distances >1/2 of the diameter sample only differences between edge locations (Rossi et al. 1992), I determined the semivariance for a 500-m radius around each survey site (or 1,000-m maximum separation). I used a random subsample of 5% of the pixels (n = 251) within each site to generate 31,375 pair combinations. Number of pairs within each distance category ranged from 24 - 986 (30-50 are a recommended minimum; Rossi et al. 1992).

A log-log plot of γ as a function of h measured spatial predictability (Rossi et al. 1992). Sites with no spatial predictability between points (i.e., random values) have slope = 0 (Palmer 1988). Conversely, sites with high spatial predictability have slopes along the 45° identity line (Palmer 1988). Typically, the function follows the identity over short increments of distances between points but reaches an asymptote as more distant points become dissimilar (Phillips 1985). I used the semivariance slope to measure habitat heterogeneity. Average patch size for each site was determined by fitting a negative exponential function to the semivariogram and estimating the distance at 75% of the asymptote.

I used logistic regression to compare the sample of used sites with the available sample (PROC

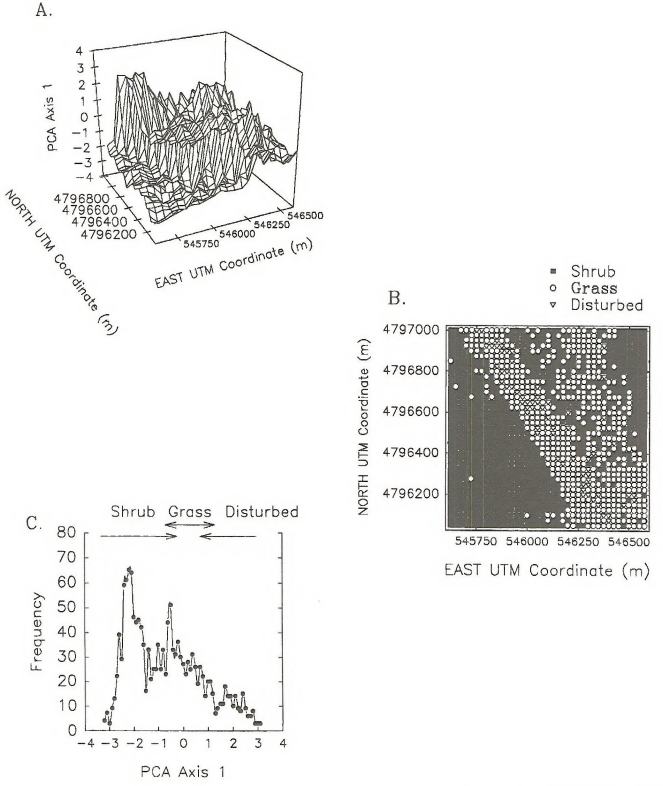

Fig. 3. Scored PCA axis 1 values (A), habitat type from translated satellite image (B), and distribution of PCA axis 1 scores with habitat associations (C) for site ISA284.

LOGISTIC, SAS Statistical Institute 1990). All variables were initially entered in a backwards elimination procedure (Manly et al. 1993). At successive steps, the least significant variable is removed if it does not contribute to significant differences ($P < 0.05$) in the model fit to the data until no variables remaining in the model meet this criterion.

Jackrabbits

Density Estimates.—Jackrabbits were counted by spotlight at night between 2200 and 0500 hr (Smith and Nydegger 1985) in spring and between 1800 and 0600 in winter by driving along previously established transects (Doremus et al. 1989). Winter surveys were conducted between 22 November 1992 and 8 January 1993. Spring surveys were conducted between 3 May and 18 June 1993. Each transect was driven 2 times on separate nights. The same transects were sampled in both winter and spring surveys.

Because of potential differences in density estimates between new transects added in 1991 and 1992 (Knick 1991) and historical transects, I compared the distribution of sighting distances and the density estimates between new and historical transects before pooling data to analyze population trend. Mean location of sample distances obtained on new and historical transects was compared by Wilcoxon 2-sample test (PROC NPAR1WAY, SAS Statistical Institute 1988) and their distribution by Kolmogorov-Smirnov 2-sample test (PROC NPAR1WAY, SAS Statistical Institute 1988) to determine if detection differences were present. Density estimates from new and historical transects were then compared by z test. A similar procedure was followed for all other pairwise comparison of transect results.

Densities of jackrabbits for 1993 and all previous years (1977-92) were estimated using program DISTANCE (Laake et al. 1991), an upgraded version of the program TRANSECT (Burnham et al. 1980). The half-normal model provided the best fit for all data sets (Lebreton et al. 1991, Burnham and Anderson 1992) and was used for density estimates.

I compared estimates of jackrabbit densities between OTA and non-OTA transects north of the Snake River to determine regional differences based on presence of military training. I also compared jackrabbit densities north and south of the drift fence to determine regional differences relative to season of livestock grazing. All comparisons were done separately for winter and spring surveys.

Sightings of kangaroo rats, Nuttall's cottontail rabbits, pygmy rabbits, and mice and voles also were recorded on black-tailed jackrabbit spotlight transects. Number of sightings was not converted into a density estimate for these species.

Black-tailed Jackrabbits and Habitats.—In 1993, we mapped all jackrabbit routes (except the Range 3 route in the Impact Area of the OTA) with a global positioning system and transferred jackrabbit sighting locations into the ARC/INFO GIS system. Location of jackrabbit sightings were then transferred onto census routes using the Dynamic Line Segmentation routine in ARC/INFO. We mapped locations of jackrabbit sightings from spring 1988 through 1993 and winter 1990-91 through 1992-93 to cover a peak in the population cycle.

RESULTS

Townsend's Ground Squirrels and Habitats

Calibration Transects for Burrow Counts.—The slope of burrow numbers over time within individual activity and certainty categories was significantly different from 0 (t test of H_0: slope = 0, $P < 0.05$) for all calibration transects during the sampling interval. However, total number of burrows on each site was relatively stable; burrow numbers significantly declined only in native/exotic grass calibration site (Fig. 4). Therefore, I used total numbers of burrows, rather than individual categories, at each site in the analyses. Trends in total number of burrows suggest that numbers were relatively stable and I grouped all samples within the sampling period.

Burrow Count Results.—I present the burrow counts for historical and random transects to identify trends only. Burrow numbers were total counts and were not adjusted. Total number of burrows counted on 47 historical transects averaged 216.3 ± 23.0 burrows/ha ($\bar{x}$ ± S.E.) and was higher than number of burrows counted in 1992 (196.3 ± 21.8 burrows/ha) (Fig. 5).

Total number of burrows counted on 183 randomly located transects averaged 189.0 ± 9.3

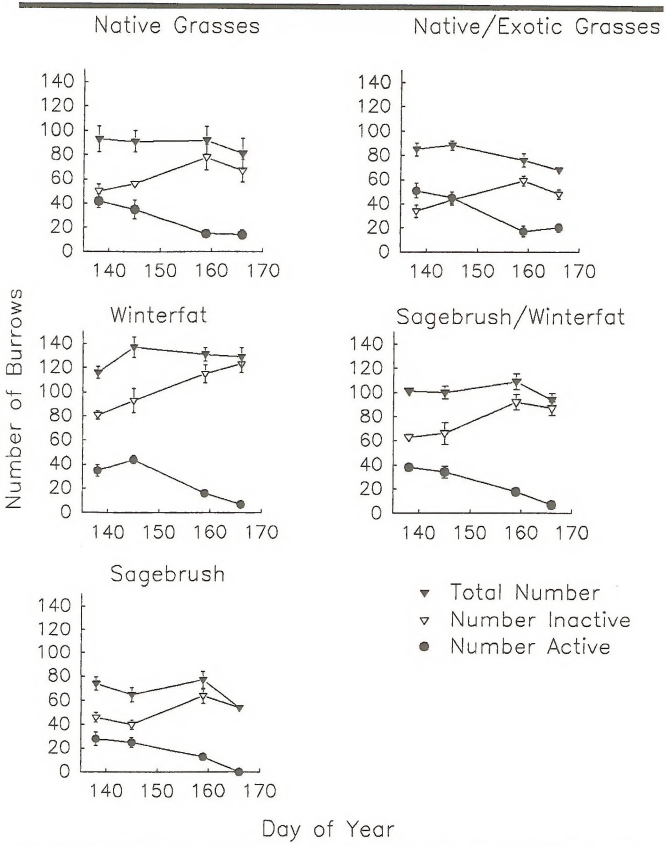

Fig. 4. Trend in active, inactive, and total numbers of burrows counted on calibration transects in 5 habitat types during the 1993 sampling period.

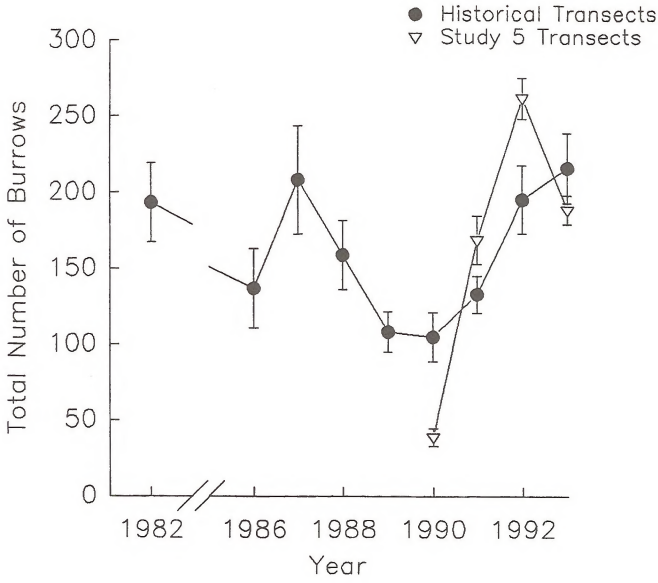

Fig. 5. Trends in numbers of total burrows counted on historical transects from 1982-1993 and transects established by Study 5 from 1990-1993.

compared to 262.0 ± 13.6 burrows/ha counted for randomly established transects in 1992 (n = 166) and 169.0 ± 15.8 in 1991 (n = 115) (Fig. 5). Burrow counts at 14 sites near agriculture fields averaged 275.0 ± 46.35 in 1993 compared to 257.14 ± 30.60 for 14 agriculture sites sampled in 1992.

Townsend's Ground Squirrels and Habitats.—Percent cover of native grasses (arcsine transformation) was the only significant variable remaining in development of a resource selection model by logistic regression (Table 2). The initial variables removed in the model building steps were exotic vegetation and shrubs, followed by landscape characteristics. Although percent cover of native grasses was a significant coefficient, the final regression model did not fit the logistic model well (χ^2 = 4.57, 1 df, P = 0.033). Two states of probability of occupancy were predicted for a given level of native grass cover (Fig. 6). At the highest cover values of native grasses, the predicted probability of occupancy suggests an unstable condition (Fig. 6).

Vegetation and Soils Analysis

Plant species richness ranged from 3 to 23 on 160 randomly selected sites; diversity ranged from 1.2 to 9.5. Both species richness and diversity were similar among shrub, grass, and disturbed habitats as well as within individual habitat classes (2-way ANOVA, F test, P > 0.10). However, both richness and diversity were significantly greater in 1993 compared to 1992 and 1991 (Table 3). Species diversity also had a significant habitat*year interaction ($F_{4,303}$ = 2.87, P = 0.024). Diversity was greater in disturbed habitats in 1993 (H = 3.3 ± 1.0 SD, n = 30) than in disturbed habitats sampled in 1992 (H = 1.7 ± 0.6, n = 16).

Table 2. Coefficients of a logistic regression model fitted to habitat characteristics and high density sites of Townsend's ground squirrels.

Variable	Coefficient	Standard Error	Wald χ^2	P>χ^2
Constant	-1.299	0.220	34.787	0.0001
Native Grass	0.649	0.331	3.850	0.0498

Table 3. Plant species richness and diversity on randomly sampled sites in the Integration Study Area north of the Snake River from 1991 through 1993. Species richness and diversity were significantly different between years.

	Habitat Group								
	Shrub			Grass			Disturb		
Year	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD
Species Richness[a]									
1991	13	6.1	1.4	47	7.0	2.6	18	6.2	2.1
1992	11	4.9	1.9	87	5.0	1.7	16	4.5	1.7
1993	4	8.5	3.1	78	8.3	2.8	30	8.6	2.1
Species Diversity[b]									
1991	13	2.3	0.3	47	2.7	1.0	18	2.2	0.8
1992	11	1.9	0.6	87	2.3	1.0	16	1.7	0.6
1993	4	2.8	0.7	78	2.9	1.1	30	3.3	1.1

[a] 2-Way ANOVA, Year Effect, $F_{2,303}$ = 26.50, P < 0.001
[b] 2-Way ANOVA, Year Effect, $F_{2,303}$ = 10.68, P < 0.001

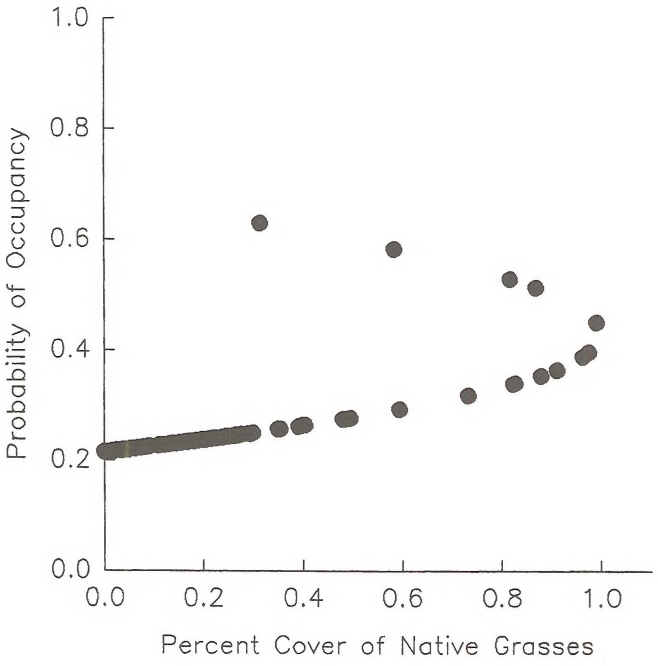

Fig. 6. Predicted probability of occupancy by a high density Townsend's ground squirrel population relative to percent cover of native grasses.

Military Use.—Only habitats 1B1 (low density sagebrush), 1D3 (disturbed), and 2A2 (low density grasses) had sufficient sample sizes in an analysis of species richness, diversity and percent cover of shrubs, grasses, and exotic plants by military tracking category and year controlled for habitat on the OTA. Within habitat 1B1, the high category of military incidence had significantly lower ($P = 0.08$) species richness (6.18 ± 0.40, $n = 4$) and lower percent cover of exotic plants (2.15 ± 0.62, $n = 4$) when compared to sites with low military tracking incidence (S = 7.00 ± 1.35, % exotics = 10.25 ± 4.01; $n = 17$) (Table 4). All other significant interactions were related to year of sampling (Table 5).

Percent ground cover of military tracks in the Orchard Training Area averaged 1.42 ± 0.44 (range 0-36.1, $n = 128$) and was independent of habitat or year of sampling (Table 6).

Livestock Use.—Only habitat types 1A1, 1B1, 1D3, and 2A2 had sufficient sample sizes in all cells of a 3-way ANOVA of species richness, diversity and percent cover of shrubs, grasses, and exotic plants by category of livestock presence (low, high) and area, and year controlled for habitat. Within habitat 2A2, sites with a high incidence of livestock had significantly higher ($P = 0.01$) percent cover of exotic plants when compared to sites with low incidence of livestock

Table 4. Summary of 2-way ANOVA for test of differences in species richness, diversity, and percent cover of shrubs, grasses, and exotic plants by military category and sample year controlled by habitat class for sites sampled in the Orchard Training Area. Only low density sagebrush (1B1), disturbed (1D3), and low density grasses (2A2) had sufficient samples within cells for the analysis. Low density sagebrush was not sampled in 1993. Significance was determined from the type III sum of squares in the full 2-way interaction model.

		Habitat Class								
		Sagebrush (1B1)			Disturbed (1D3)			Grassland (2A2)		
Variable	Effect	*F*	df	*P*	*F*	df	*P*	*F*	df	*P*
Richness	Year	12.52	1,20	0.01	6.46	2,12	0.02	16.22	2,49	0.01
	Mil.	3.52	1,20	0.08						
	Year*Mil.	4.26	1,20	0.05						
Diversity	Year	13.82	1,20	0.01	5.67	2,12	0.03	6.66	2,49	0.01
Exotics (%)	Mil.	7.28	1,20	0.02						
	Year							6.60	2,49	0.01

Table 5. Species richness, diversity, and percent cover of shrubs, grasses, and exotic plants by sample year for low density sagebrush (1B1), disturbed (1D3), and low density grass (2A2) habitats in the Orchard Training Area. Summary of 2-way ANOVA statistics are presented in Table 6.

		S		H		Shrub %		Grass %		Exotic %	
Year	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1B1											
1991	5	8.0	0.8	4.1	0.4	11.5	2.1	8.3	1.8	4.3	1.2
1992	16	5.8	0.4	2.7	0.2	11.9	1.4	7.4	1.2	3.5	1.4
1D3											
1991	5	6.6	0.4	2.7	0.4	0.1	0.1	8.3	2.7	27.1	1.8
1992	7	4.3	0.6	1.7	0.2	0.0	0.0	3.5	1.7	25.1	2.4
1993	1	9.0		4.0		0.0		11.4		17.5	
2A2											
1991	11	7.5	0.7	3.5	0.3	0.5	0.3	11.7	1.8	10.5	1.8
1992	32	4.7	0.3	2.3	0.2	0.9	0.4	10.3	1.3	3.0	0.7
1993	7	8.7	0.7	3.4	0.3	0.0	0.0	12.1	3.6	7.5	4.0

Table 6. Summary of 2-Way ANOVA for percent ground cover of tank tracks by habitat and sample year for sites within the Orchard Training Area.

Source	df	Sum of Squares	Mean Squares	F	P
Model	24	524.10	21.84	0.85	0.67
Error	102	2,621.01	25.70		
Total	126	3,145.11			
Type III Sum of Squares					
HAB	10	70.57	7.05	0.27	0.99
VEGYR	2	38.23	19.11	0.74	0.48
HAB*VEGYR	12	304.17	25.35	0.99	0.47

(high: 9.26 ± 0.81, n = 97; low: 5.69 ± 1.17, n = 24) (Table 7). All other significant interactions were year effects (Table 7).

Percent livestock litter in point frame analyses averaged 0.26 ± 0.02 (range 0 - 2.7, n = 445) and did not differ significantly among area, habitats, or year of sampling (Table 8).

Soils.—Soil (percent nitrates, percent organic matter, and texture: percent clay, percent silt, percent sand) and percent cover of plant species were combined for 1991 (n = 80) and 1992 (n = 92). Environmental axis 1 in the canonical correspondence analysis of vegetation species and soils (environmental variables) represented a gradient of subsurface organic matter (r = 0.655); axis 2 was a texture gradient from surface silt (r = 0.553) to surface sand (r = -0.687) (Fig. 7). The first 4 environmental axes explained only 3.1% of the total variation in species data (Table 9).

The posterior probability rate of misclassification was 46.4% in a quadratic discriminant function with habitat as the classification variable and soil variables as predictors (Table 10). Most misclassification errors were disturbed or grass sites classed as shrub sites.

Military and Livestock as Environmental Variables.—Percent ground covered by military tracks and livestock litter were uncorrelated environmental variables in a canonical correspondence analysis with vegetation species; the correlation coefficient of livestock and military tracks was -0.032. In direct gradient analyses, environmental axes are mutually uncorrelated; percent cover of tank tracks was highly correlated with environmental axis 1 (r = 0.999) and livestock litter was correlated with environmental axis 2 (r = 0.996) (Fig. 8). The vegetation species axis 1 had low correlations with environmental axes 1 (r = 0.187) and 2 (r = 0.000). Similarly, veg-

Table 7. Summary of 3-way ANOVA for test of differences in species richness, diversity, and percent cover of shrubs, grasses, and exotic plants by livestock category (high, low), area (ISA, OTA) and sample year controlled by habitat class for sites sampled in the Integration Study Area. Only high density sagebrush (1A1), low density sagebrush (1B1), disturbed (1D3), and low density grasses (2A2) had sufficient samples within cells for the analysis. High density sagebrush was not sampled in 1993. Significance was determined from the type III sum of squares from full interaction model.

Habitat	Variable	Effect	F	df	P
1A1	Richness	Year	4.77	1,22	0.04
1A1	Diversity	Year	7.89	1,22	0.01
1A1	Exotics (%)	Year	6.73	1,22	0.02
1B1	Richness	Year	7.26	2,59	0.02
1B1	Exotics (%)	Year	12.25	2,59	0.01
1D3	Richness	Year	5.16	2,32	0.01
2A2	Richness	Year	11.76	2,120	0.01
2A2	Exotics (%)	Year	7.96	2,120	0.01
2A2	Exotics (%)	Livestock	10.20	1,120	0.01

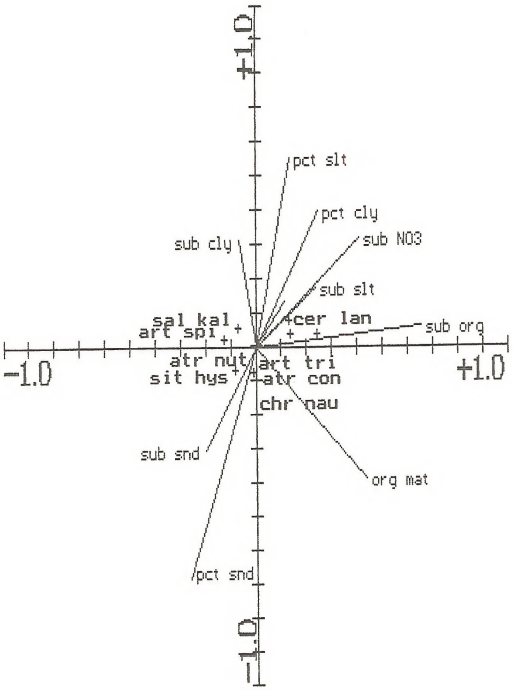

Fig. 7. Joint plot of vegetation species and soil variables from canonical correspondence analysis. Vegetation species were Bud sage (art spi), winterfat (cer lan), shadscale (atr con), cheatgrass (bro tec), green rabbitbrush (chr vis), gray rabbitbrush (chr nau), sagebrush (art tri), Nuttalls saltbush (atr nut), Russian thistle (sal kal), and bottlebrush squirreltail (sit hys). Soil variables were % surface silt (pct slt), sand (pct snd), and clay (pct cly); % subsurface silt (sub slt), sand (sub snd), and clay (sub cly); % surface nitrates (pct NO3) and % subsurface nitrates (sub NO3); and % surface organic matter (pct org) and % subsurface organic matter (sub org).

Table 8. Summary of 3-Way ANOVA for percent ground cover of livestock litter by area (ISA vs OTA), habitat type, and sample year.

Source	df	Sum of Squares	Mean Squares	*F*	*P*
Model	50	11.26	0.23	1.27	0.12
Error	343	61.06	0.18		
Total	393	72.32			
Type III Sum of Squares					
AREA	1	0.02	0.02	0.11	0.74
HAB	14	2.09	0.15	0.84	0.63
VEGYR	2	0.44	0.22	1.22	0.30
AREA*HAB	9	1.93	0.21	1.20	0.29
HAB*VEGYR	21	1.83	0.09	0.49	0.97
AREA*VEGYR	2	0.04	0.02	0.10	0.90

Table 9. Canonical correspondence analysis of plant species with soils (environmental variables) at 172 sites sampled for vegetation and soils in 1991 and 1992.

	Canonical Correspondence Analysis Axes			
	1	2	3	4
Eigenvalues	0.058	0.045	0.023	0.019
Species-environment correlations	0.350	0.289	0.270	0.193
Cumulative percentage variance				
species data	1.3	2.2	2.7	3.1
species-environment relation:	32.7	58.0	71.2	81.7
Sum of all unconstrained eigenvalues	4.653			
Sum of all canonical eigenvalues	0.178			

Table 10. Error matrix of sites classed for habitat type with soil variables as predictors in a quadratic discriminant analysis.

Known Habitat Class	Classified by quadratic discriminant function												
	1A1	1B1	1B2	1B3	1B5	1B7	1B8	1D3	1D4	2A1	2A2	2B2	Total
1A1	12												12
1B1	6	19						4					29
1B2			6										6
1B3				12									12
1B5					3								3
1B7						2							2
1B8							3						3
1D3	2	6						11					19
1D4									2				2
2A1										5			5
2A2	9	34						11			11		65
2B2	1	5										4	10
Total	30	65	6	12	3	2	3	26	2	5	11	4	169

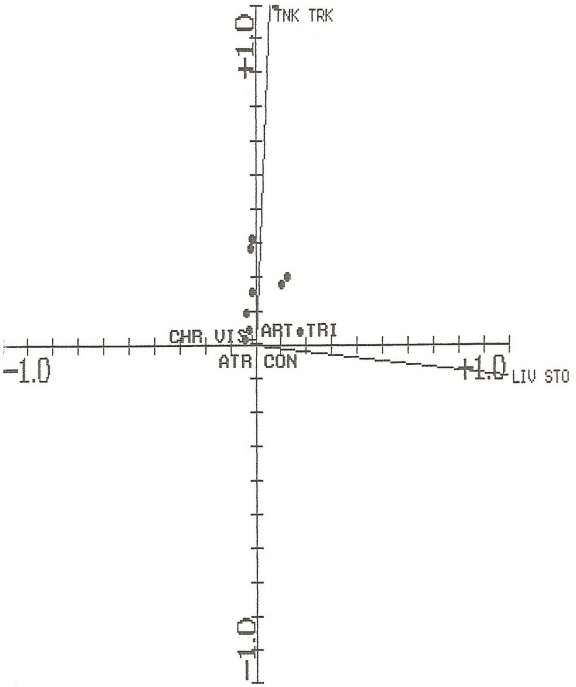

Fig. 8. Triplot of vegetation species, environmental variables (Livestock and tank tracks), and sampling sites.

Table 11. Canonical correspondence analysis of plant species with percent cover of military tracking and livestock litter (environmental variables) at 445 sites sampled in the Integration Study Area from 1991 through 1993.

	Canonical Correspondence Analysis Axes			
	1	2	3	4
Eigenvalues	0.018	0.008	0.685	0.532
Species-environment correlations	0.187	0.140	0.000	0.000
Cumulative percentage variance				
of species data	0.4	0.6	15.9	27.7
of species-environment relation	68.5	100.0	0.0	0.0
Sum of all unconstrained eigenvalues	4.483			
Sum of all canonical eigenvalues	0.026			

etation species axis 2 was not correlated with environmental axes 1 ($r = 0$) or 2 (0.140). The cumulative percent variance of species data explained in the first 2 environmental axes was only 0.6 (Table 11). Military tracking was independent of vegetation species but was associated with OTA sites (Fig. 8).

Black-tailed Jackrabbits

Density Estimates.—Winter 1992-93 densities of black-tailed jackrabbits along all spotlight transect routes (660.32 km) were 0.07 jackrabbits/ha (0.06-0.08, 95% C.I.) compared to 0.15 jackrabbits/ha (0.13-0.18, 95% C.I.) in winter 1991-92. Density estimates for 14 traditional transects did not differ from new transects added by Study 5 (Table 12).

Spring jackrabbit densities declined in 1993 compared to 1991 and 1992 (Fig. 9). Jackrabbit sightings in spring surveys were significantly higher on historical transects compared to transects established by Study 5 (Table 13).

Spring jackrabbit densities were significantly higher on transects inside the OTA than outside the OTA (Table 13). Density estimates were higher south of the Snake River during winter surveys but were similar during the spring. Jackrabbit densities were higher on transects south of the grazing drift fence during winter surveys but significantly lower during spring surveys (Tables 12, 13).

We also observed 3 Nuttall's cottontail rabbits, 531 kangaroo rats, and 15 mice and voles on spring spotlight transects. On winter transects, we counted 4 Nuttall's cottontail rabbits, 1 pygmy rabbit, 92 kangaroo rats, and 1 deer mouse.

Black-tailed Jackrabbits and Habitats.—All transect routes, except Range 3 in the Impact Area of the OTA were mapped by global positioning system and imported into ARC/INFO. Sighting locations from night spotlight surveys were imported onto the transects using the dynamic line segmentation functions in ARC GRID

Table 12. Pairwise comparisons of rabbit density estimates for winter 1992-93 surveys.

Transect	km	*n*	D	95% C.I.	*z*	*P*
Historical	467.08	312	0.073	0.061-0.087	1.05	n.s.
Study 5 New	193.24	98	0.061	0.045-0.082		
ISA	411.12	180	0.054	0.043-0.066	2.95	0.01
OTA	119.08	151	0.106	0.078-0.144		
N. Drift Fence	141.54	66	0.041	0.030-0.056	2.30	0.05
S. Drift Fence	388.74	265	0.064	0.055-0.075		
N. Snake River	530.28	331	0.065	0.055-0.077	2.61	0.01
S. Snake River	101.24	79	0.104	0.035-0.075		

Table 13. Pairwise comparisons of rabbit density estimates for spring 1993 surveys.

Transect	km	*n*	D	95% C.I.	*z*	*P*
Historical	467.08	198	0.069	0.056-0.085	3.92	0.001
Study 5 New	193.24	43	0.032	0.024-0.046		
ISA	411.12	92	0.031	0.024-0.039	5.53	0.001
OTA	119.08	112	0.150	0.112-0.194		
N. Drift Fence	141.54	84	0.074	0.057-0.095	2.01	0.05
S. Drift Fence	388.74	120	0.050	0.038-0.065		
N. Snake River	530.28	204	0.063	0.051-0.077	0.099	n.s.
S. Snake River	101.24	37	0.051	0.035-0.075		

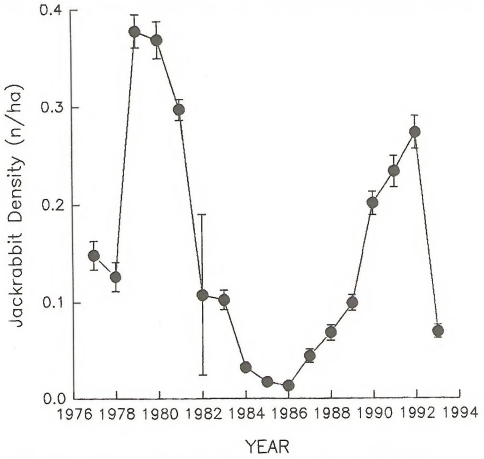

Fig. 9. Spring estimates of jackrabbit densities (± coefficient of variation) for the Snake River Birds of Prey Area from 1977 through 1993.

for spring 1988 through 1993 and winter 1990-91 through 1992-93. Limitations of the ARC/INFO version prevented conversion of locations into grid coordinates and subsequent analysis for habitat associations. A method to map jackrabbit habitat suitability is proposed in the Discussion.

DISCUSSION

Results are discussed in the context of the principal research questions of the BLM/IDARNG Research Project.

What soil and vegetation characteristics are associated with abundance of Townsend's ground squirrels and black-tailed jackrabbits?

Strong correlation of abundance of Townsend's ground squirrels with the burrow count index remains unsubstantiated after 4 years of testing this index (Knick 1990, 1991, 1992, Van Horne et al. 1991, Van Horne et al. 1992, this volume). Interpretation of population trends from historical transects, as well as correlations between populations and habitat characteristics on new sample sites, remains linked to several factors. First, the relationship between any category or total numbers of burrows and actual numbers of ground squirrels in the population is still unsupported. Second, observer bias further confounds interpretations of this index. Finally, use of other than categorical estimates (high, low) implies far greater precision to habitat differences identified from burrow counts than with the extensive mark-recapture program of Study 4 (K.P. Burnham, U.S. Fish and Wildlife Service, pers. commun.). A statistically significant response in burrow counts that differ by 25% does not convey the same, and may even falsely represent, the right population response. Therefore, only categorical estimates of population density (high or low) from burrow counts may be crudely accurate. However, even this assumption was not valid in 1993 comparisons of burrow counts with estimates of ground squirrel densities (Van Horne et al., this volume). Comparisons between habitats or years that use burrow counts as a population index remain unsubstantiated and we recommend a monitoring program based on a small-scale livetrapping program rather than burrow counts.

A relationship between burrows of Townsend's ground squirrels and percent cover of native grasses was significant in development of a resource selection model by logistic regression. The predicted pattern of occupancy relative to percent cover of native grasses suggested that >1 population state is likely for any given cover value of native grasses. At extremely high cover values of native grasses, populations also are likely to be unstable. Evidence of multiple population states may explain previous difficulty in attempts to relate a single population mean to habitat characteristics (Knick 1991, 1992).

Jackrabbits have been censused in the Snake River Birds of Prey Area by night spotlight counts using line transect methods since 1977 (Wolfe et al. 1977). Black-tailed jackrabbits are cyclic with approximate 7-12 year intervals between peaks (Johnson and Peek 1984). In the Snake River Birds of Prey Area, densities peaked in 1979 and again in 1990-92. Estimates of jackrabbit densities decreased in 1993 from 1991 and 1992 levels.

The differences in estimates of jackrabbit densities relative to the grazing drift fence between winter and spring surveys may represent differential population dynamics or seasonal movements. Seasonal movements of jackrabbits were documented in southeastern Idaho (Grant 1987) and northern Utah (Smith 1990).

I propose to develop a habitat map of habitat-use potential (Clark et al. 1993) for black-tailed jackrabbits from the sighting locations on rabbit surveys and multiple GIS layers. Habitat variables, such as diversity, habitat type, distance to watering tanks, or any contoured variable, will be used to develop a mean vector of ideal habitat characteristics from sight locations. The vector of habitat characteristics associated with each cell in the GIS map can then be used to generate the Mahalanobis distance statistic, a measure of dissimilarity from the ideal habitat vector. A map of probability of each cell being a ideal habitat cell can be produced by recoding the Mahalanobis distance statistic into an associated Chi-square probability (Clark et al. 1993). The resulting map would provide a spatial representation of areas consisting of jackrabbit habitats.

Have changes in vegetation resulting from wildfires affected the abundance of Townsend's ground squirrels and black-tailed jackrabbits?

This question will be answered when the burn map is developed.

Do military training activities affect abundance of Townsend's ground squirrels and black-tailed jackrabbits on either a short- or long-term basis?

Percent cover of military tracks was not a significant variable in the logistic regression for burrow counts of ground squirrels and habitats. Military training also was not a significant environmental variable in the canonical correspondence analysis. Results from the analyses of variances suggest that variables related to sampling year, such as rainfall and length of growing season, have a stronger influence on short-term vegetation characteristics than military training. Influence of military tracking may be more likely mediated in long-term vegetation changes. High incidence of military tracking was associated with lower species richness and lower percent cover of exotic plants. These results are not cause and effect, but rather correlative: military training does not necessarily result in lower species richness and lower percent cover of exotic plants. The simplest explanation may be that training in 1993 occurred more often in areas with these characteristics.

Do prey densities or vegetation and soil characteristics favored by prey vary with livestock use?

Percent cover of livestock litter was not a significant variable in the logistic regression model of ground squirrel burrows and habitats.

Percent cover of livestock litter also was not a significant environmental variable in the canonical correspondence analysis. Livestock use was uniformly distributed at a gross scale and did not differ between the OTA or ISA, or by habitat type. Within low density grasslands (2A2), sites with a high incidence of livestock tracks also had a higher percent cover of exotic plants. Again, the study design does not permit analysis for cause and effect, only associations.

PLANS FOR NEXT YEAR

Townsend's Ground Squirrels and Habitats

The 1993 Integration Workshop made it clear that burrow counts are not reliable indexes of Townsend's ground squirrel abundance. Thus, we will not count burrows this year. Instead, we will initiate an intensive livetrapping program on approximately 50 newly established sites to determine population sizes. The trapping design and schedules will be determined with assistance from Study 4.

We will test the ability of a habitat-based model, in cooperation with Study 4, to predict ground squirrel abundance. This model will be based primarily on the percent cover of green Sandberg's bluegrass. We will test this model with ground squirrel and vegetation data collected from 50 sites on which livetrapping will be conducted.

We will analyze spatial dynamics using the habitat based model developed by study 4 as the population index, after consideration of its validity. If numbers of Townsend's ground squirrels can be related in space and time, changes in that process can then be evaluated for the source of that disruption. One approach to be evaluated will use canonical correspondence analysis (ter Braak 1986) to separate species variation into environmental and spatial partitions (Borcard et al. 1992).

Development of the burn map in 1994 will permit analysis of spatial relationships of burns and distribution of Townsend's ground squirrels and habitats. The method used to map habitats for black-tailed jackrabbits (Clark et al. 1993) can be extended to an analysis of suitability (or probability of occupancy) of Townsend's ground squirrel habitats in burns.

We will conduct all Townsend's ground squirrel livetrapping during the month of April to coincide with the time they are most active above ground. Each site will be trapped for 3 days in an attempt to capture all animals in the population. Individuals trapped will be marked prior to release to avoid over counting. Vegetation surveys will be conducted at each site where ground squirrels are marked.

Vegetation and Soils

We will sample habitats at 125-175 new sites randomly selected within the (ISA) of the SRBOPA, including the OTA. The number of sites will be apportioned between the OTA and the non-OTA relative to their respective areas. We will differentiate between green and brown Sandberg's bluegrass (*Poa secunda*) in an attempt to better correlate vegetation with ground squirrel numbers. Because of the need to conduct livetrapping

within a limited period, the sites will be revisited to sample vegetation after the livetrapping is concluded.

The relationship between soils and vegetation will be further examined with 100 samples collected at 1993 study sites and analyzed at the University of Idaho. Establishing links between soil variables and vegetation may provide insights into effects of disturbance on vegetation.

Black-tailed Jackrabbits

We will continue spotlight counts to estimate spring and winter densities. We will survey all transects throughout the SRBOPA by spotlight methods (Smith and Nydegger 1985). Habitat use maps will be developed on the GIS as described above. Predictions from this map will be tested from sightings in 1994 surveys. Spatial and temporal analysis of contoured densities of jackrabbit densities, as well as location of ideal habitat cells may permit conclusions that can be related to major influences, such as wildfires, or in evaluation of golden eagle (*Aquila chrysaetos*) foraging.

Development of the burn map in 1994 will permit analysis of spatial relationships of burn and distribution of Townsend's ground squirrels and habitats. The method to map habitats for black-tailed jackrabbits (Clark et al. 1993) can be extended to an analysis of suitability (or probability of occupancy) of habitats in burns. The technique also could be used for habitats of Townsend's ground squirrels.

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Appendix A. Acronym, scientific, and common names for plant species identified at random sampling sites by Study 5 of the BLM/Idaho Army National Guard Research Project, 1991 through 1993.

Acronym	Scientific Name	Common Name
agcr	*Agropyron cristatum*	Fairway crested wheatgrass
agde	*Agropyron desertorum*	Standard crested wheatgrass
agdi	*Agrostis stolonifera*	Redtop bentgrass
agel	*Agropyron elongatum*	Tall wheatgrass
agri	*Agropyron riparium*	Streambank wheatgrass
agsm	*Agropyron smithii*	Western wheatgrass
agsp	*Agropyron spicatum*	Bluebunch wheatgrass
alac	*Allium acuminatum*	Tapertip onion
amal	*Amaranthus albus*	Pigweed amaranth
amca	*Amaranthus californicus*	California amaranth
amre	*Amaranthus retroflexus*	Redroot amaranth
amte	*Amsinckia tessellata*	Western fiddleneck
arca	*Artemisia cana*	Silver sagebrush
arsp	*Artemisia spinescens*	Bud sagebrush
artr	*Artemisia tridentata*	Big sagebrush
atca	*Atriplex canescens*	Fourwing saltbush
atco	*Atriples confertifolia*	Shadscale saltbush
atnu	*Atriplex nuttallii*	Nuttall saltbush
baho	*Balsamorhiza hookeri*	Hooker balsamroot
brru	*Bromus rubens*	Foxtail brome
brte	*Bromus tectorum*	Cheatgrass brome
cabr4	*Calochortus bruneaunis*	Bruneau mariposa lily
cela	*Ceratoides lanata*	Winterfat
chfr	*Chenopodium fremontii*	Fremont goosefoot
chle	*Chrysanthemum leucanthemum*	Oxeye chrysanthemum
chna	*Chrysothamnus nauseosus*	Gray rabbitbrush
chte	*Chorispora tenella*	Common bluemustard
chvi	*Chrysothamnus viscidiflorus*	Green rabbitbrush
coca	*Conyza canadensis*	Canada horseweed
conu	*Coldenia nuttallii*	Nuttall coldenia
crac	*Crepis acuminata*	Tapertip hawksbeard
crba	*Crepis bakeri*	Bakers hawksbeard
debi	*Delphinium bicolor*	Low larkspur
depi	*Descurainia pinnata*	Pinnate tansymustard
deso	*Descurainia sophia*	Flixweed tansymustard
drve2	*Draba verna*	Spring draba
elan	*Elaeagnus angustifolia*	Russian olive
elci	*Elymus cinereus*	Basin wildrye
elju	*Elymus junceus*	Russian wildrye
eppa	*Epilobium paniculatum*	Autumn willowweed
eran	*Erigeron annuus*	Annual fleabane
ercl	*Erodium cicutarium*	Cutleaf filaree
ergl	*Erigeron glabellus*	Smooth fleabane
ervi	*Eriogonum vimineum*	Vim eriogonum
gisi	*Gilia sinuata*	Largeleafrosy gilia
grsp	*Grayia spinosa*	Spiny hopsage
hagl	*Halogeton glomeratus*	Halogeton
hean	*Helanthus annuus*	Common sunflower
ivax	*Iva axillaris*	Rag sumpweed
jubu	*Juncus bufonius*	Toad rush
koam	*Kochia americanus*	Greenmolly summercypress
kosc	*Kochia scoparia*	Belvedere summercypress
lapu	*Langloisia punctata*	Greatbasin langloisia
lare	*Lappula redowskii*	Redowski tickseed
lase	*Lactuca serriola*	Prickly lettuce
lepe	*Lepidium perfoliatum*	Clasping pepperweed
libu	*Lithophragma bulbifera*	Bulbous woodlandstar
lodi	*Lomatium dissectum*	Fernleaf biscuitroot

Appendix A (cont.)

Acronym	Scientific Name	Common Name
lupu	*Lupinus pusillus*	Low lupine
maca	*Machaeranthera canescens*	Hoary machaeranthera
magl2	*Madia glomerata*	Cluster tarweed
meal	*Mentzelia albicaulis*	Whitestem blazingstar
migr	*Microsteris gracilis*	Slender falsephlox
myar	*Myosurus aristatus*	Bristle mousetail
mymi	*Myosotis micrantha*	Smallflower forgetmenot
nadi	*Navarretia divaricata*	Divaricate navarretia
orhy	*Oryzopsis hymenoides*	Indian ricegrass
phac	*Phlox aculeata*	Sagebrush phlox
phho	*Phlox hoodii*	Hoods phlox
plsc	*Plagiobothrys scouleri*	Scouler popcornflower
plte	*Plagiobothrys tennellus*	Slender popcornflower
poav	*Polygonum aviculare*	Prostrate knotweed
pose	*Poa secunda*	Sandberg bluegrass
rate	*Ranunculus testiculatus*	Bur buttercup
rucr	*Rumex crispus*	Curly dock
saib	*Salsola iberica*	Saltwort
save	*Sarcobatus vermiculatus*	Black greasewood
sial	*Sisymbrium altissimum*	Tall tumblemustard
sihy	*Sitanion hystrix*	Bottlebrush squirreltail
spmu	*Sphaeralcea munroana*	Munro globemallow
stco	*Stipa comata*	Needleandthread grass
stth	*Stipa thurberiana*	Thurber needlegrass
suin	*Suaeda intermedia*	Intermediate seepweed
taof	*Taraxicum officinale*	Common dandelion
tegl	*Tetradymia glabrata*	Littleleaf horsebrush
trag	*Trifolium agrarium*	Hop clover
trdu	*Trifolium dubium*	Clover
trma	*Trifolium macrocephalum*	Bighead clover
veth	*Verbascum thapsus*	Flannel mullein
vuoc	*Vulpia octoflora*	Sixweeks fescue
zypa	*Zygadenus paniculatus*	Foothill deathcamas

Use of Satellite Imagery to Delineate Habitats in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*We updated our habitat classification scheme based on vegetation samples from 1991 and 1993 by Study 5 of the BLM/IDARNG Research Project. The habitat classification now has shrub classes of four-winged saltbush (**Atriplex canescens**), spiny hopsage (**Grayia spinosa**), and little-leaf horse-brush (**Tetradymia glabrata**) to reflect vegetation south of the Snake River. The statistical error rate for habitat classification of 3,027 samples was 9.3% and represents the inherent variation in the vegetation.*

We have completed an initial translation of the satellite images into vegetation classes for the Integration Study Area (ISA) north of the Snake River. A new set of calibration points was developed from vegetation samples south of the Snake River. To date, approximately half of the ISA south of the Snake River, including a 2-km buffer has been translated.

*Three sources of errors in habitat classification are consistent in the vegetation data, field estimates, and image translation: (1) separation of density classes of shrublands, (2) separation of low density shrubs from grasslands, and (3) distinction between grassland and disturbed classes dominated by Russian thistle (**Salsola iberica**).*

OBJECTIVES

1. To develop a habitat classification for the Snake River Birds of Prey Area.

2. To determine the relationship between vegetation and spectral qualities in Thematic Mapper satellite imagery.

3. To create a vegetation map from satellite imagery for the Snake River Birds of Prey Area.

INTRODUCTION

Accurate maps of habitats are essential for relating organisms to spatial elements in the environment. Until recently, habitat maps were created by interpreting aerial photographs or by intensive ground-based sampling. Computer software for image processing coupled with Geographic Information Systems now permit creation of habitat maps from satellite images.

Remote sensing of the earth from satellite platforms is emerging as a powerful tool to obtain fine-grained information for large regions (Roughgarden et al. 1991). Data from satellites, when correlated with ground characteristics, can be used to assess vegetative cover (Richardson and Wiegand 1977, Tucker 1979, Running et al. 1989), quantify habitats used by wildlife (Robertson et al. 1990, Shaw and Atkinson 1990), describe landscape features (Milne 1992), and detect temporal change in earth resources (Hall et al. 1991a, Price et al. 1992).

Delineation and analysis of forested regions and agricultural croplands by satellite imagery has been successful. However, habitats in rangelands and other arid ecosystems are more difficult to delineate because the ground cover of vegetation and photosynthetic material is relatively low compared to other influences, such as soil reflectance, on spectral quality (Ustin et al. 1985, Tueller 1987). Spectral responses in satellite imagery also are less sensitive to desert vegetation because the relatively simple vegetative structure has minimal influence on reflective and refractive radiation.

In this report, we discuss our habitat classification, image translation methods, and error assessment in developing vegetation maps from satellite imagery in a semiarid rangeland. This effort (Knick et al. 1991, Knick et al. 1992a, b) involves interaction of field surveys and computer processing in image processing and Geographical Information Systems (Fig. 1).

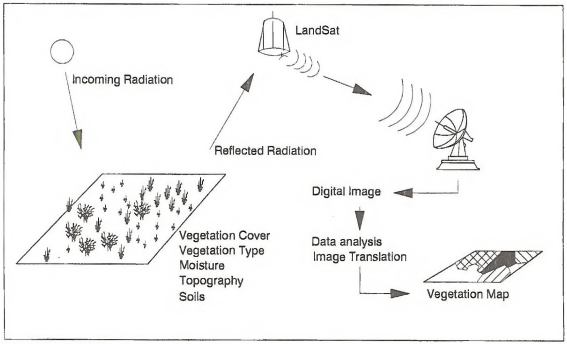

Fig. 1. Pathways in the process of creating a vegetation map from a remote sensing platform.

METHOD

Study Area

The Snake River Birds of Prey Area (SRBOPA) (116° E Long, 43° N Lat) includes approximately 195,325 ha of Great Basin desert rangeland in southwestern Idaho. Once predominantly shrubland, approximately one-half of the shrubland in the SRBOPA has burned since 1975 and is now dominated by cheatgrass (*Bromus tectorum*) and Russian thistle (Kochert and Pellant 1986). Big sagebrush (*Artemisia tridentata*) communities dominate the region in the north and grade into salt shrub communities in the south (Yensen and Smith 1983). Livestock grazing and military training are the primary land-use activities (Kochert and Pellant 1986). Weather in the SRBOPA is characterized by hot, dry summers and cold winters. Maximum daily temperature from 1955 to 1989 averaged 30-36 C during June-August and 5-9 C during December-January at the Swan Falls weather station, and annual precipitation at this site averaged 26.9 cm.

Habitat Classification

Vegetation Sampling.—Percent ground cover of plant species was sampled at randomly located sites within the SRBOPA from 1991 to 1993 (Knick 1991, 1992, this volume). Size of the area sampled (the resolution of our vegetation sampling) was 25 x 25-m to match pixel size of the satellite image. Cover was sampled by point frame intercept (Floyd and Anderson 1982). Russian thistle was the only annual forb used in our analysis because of large yearly fluctuations in other forbs. Each Study 5 transect was located by a Global Positioning System to an accuracy of ±25 m.

Development of the Habitat Classification.—We determined the habitat classification from percent cover of vegetation in the individual 5-m point frame sites (Fig. 2). The site, or sample unit, refers to the 1 x 5-m area sampled by point frame. Only sites surveyed from 1991 though 1993 (n = 3,027) were included in the sample.

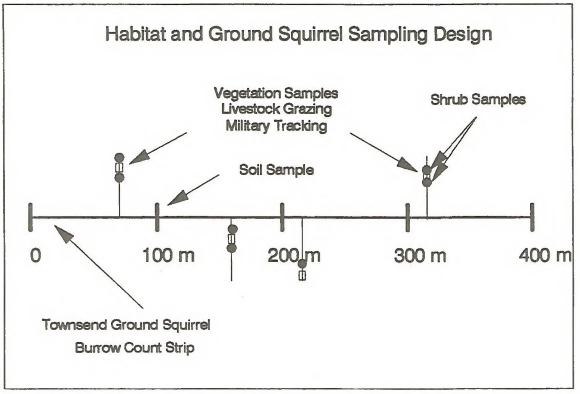

Fig. 2. Site diagram for vegetation sampling by Study 5 of the BLM/IDARNG Research Project. Individual 5-m sections of point frame coverages were used in developing the habitat classification and translation of satellite imagery into habitats.

We refined the habitat classification scheme in each subsequent year as additional vegetation surveys, conducted by Study 5 of the BLM/IDARNG Research Project (Knick 1990, 1991, 1992, this volume), were added to the pool of habitat data. Refinements in classification were made after comparing vegetation characteristics in misclassified samples with correctly classed categories from a linear discriminant analysis (PROC DISCRIM, SAS Statistical Institute 1988). Values delimiting density categories were determined from visual inspection of the distribution of percent cover values for individual plant species.

We repeated the linear discriminant analysis on the vegetation data, accepting the reclassed habitats for samples until a misclassification error <10% was attained. This error rate was a tradeoff between having sufficient number of classes to adequately describe the study area but still maintaining a statistical reliability in separating classes. For example, a single habitat, such as desert rangeland, could be classed with 100% statistical reliability but would be of little value in describing variation in vegetation at our scale of investigation. The characteristics of the reclassed habitats helped define the boundaries of our habitat types in the classification. We then developed a computer program (Turbo Pascal v6.0) to classify samples based on these cover characteristics.

Field Estimation of Habitat Classes.—The ability of field observers to identify habitats accurately was assessed by comparing statistical and field habitat assignments. Each observer (N = 2) on a Study 5 field team independently classified sites before starting the vegetation surveys. We began these tests beginning in the third week of the field surveys, after each observer was experienced with both plant identification and with our habitat classification scheme.

Vegetation Indexes and Satellite Imagery

Satellite Imagery.—We used Thematic Mapper satellite images taken on 3 September 1990 and 30 March 1991 to maximize differences in vegetation phenology and also increase our ability to separate habitat classes. Images were geocorrected to common reference points. Images were not radiometrically corrected (Hall et al. 1991b) because we were interested in maximizing variation in predictor variables rather than correcting for sensor and date differences necessary for determining transitions.

Pixel size, the resolution of the images, was 25 m, and each image consisted of 255 potential shades in each of 7 spectral bands (6 reflective, 1 thermal). Therefore, each pixel in the SRBOPA was represented by 14 spectral variables (2 images, 7 bands/image). We performed image processing and spatial analyses on the GRASS and ARC/INFO Geographical Information Systems software; statistical analyses were conducted on a PC or UNIX workstation using the SAS statistical software (SAS Statistical Institute 1988, 1990).

Vegetation Mapping from Satellite Imagery

We developed the vegetation map from satellite imagery iteratively, with continual upgrades of data sets as more information was collected (Fig. 3). The habitat classification, defining the vegetation patterns, was evaluated and refined each year. Current year's vegetation samples were first used as test data to assess the error in the ability of the images to define habitats, and then were then added to the existing pool of vegetation data for re-evaluation of the habitat classification. The most recent (and complete) set of vegetation data then defined spectral qualities of habitats at known locations and was used to develop the discriminant function to classify unknown pixels.

We determined spectral signatures, consisting of all TM band values, for each habitat class from a training set of 1,498 points with both vegetation and locational information. Location of each site was established by a Global Positioning System with an accuracy of <25 m. Vegetation sites were overlaid with the satellite imagery, and additional points were selected in water (n = 11), agriculture (n = 12), fallow (n = 13) fields, or on roadways (n = 22). Band values from each image were then output for each site to develop the multivariate function of spectral data that described each habitat type.

Image Interpretation and Development of the Habitat Map.—We used a hierarchical procedure to classify the satellite image into habitat types. First, we identified agriculture/fallow pixels by distance of the residual (DVI index) from the baseline of bare ground in the ratio developed from TM bands 4 and 3 in the 3 September 1990 image. Second, we separated the remaining

unidentified pixels into grass or shrub categories using a nonparametric discriminant function analysis (PROC DISCRIM, SAS Statistical Institute 1988, 1990) with options METHOD=NPARM, KERNEL=NORMAL, and R = 0.8. The calibration set consisted of habitat as the classification variable and spectral values as predictor variables. A second nonparametric discriminant function, specifying a smaller radius (R = 0.5), was conducted separately on shrub and nonshrub groups to identify final habitat classes.

We used the set of known habitats and locations to develop the discriminant functions used to classify the remaining unknown pixels in the image. Accuracy of the images to discriminate our habitat classes was evaluated at the second and final steps from the posterior probability estimates developed in the quadratic discriminant function for both calibration and test data. The nonparametric method of deriving a discriminant function was more appropriate than a linear approach because of the distribution of the spectral data and differences among within-group variances.

Image Translation South of the Snake River.—A second calibration set of vegetation data was developed from samples collected south of the Snake River. We also included sites within a 2-km buffer north of the river in the calibration set to increase sample sizes in some habitat classes and to minimize transitional edges. The calibration set included 689 samples and 27 habitat classes. The separate calibration set was necessary because of differences in vegetation and image characteristics.

Error Assessment of the Vegetation Map.—Two sources of error were involved in creating the vegetation map: (1) the error in classifying vegetation, and (2) the error in the imagery used to classify our habitat classes. We estimated error rates in our habitat classification with results

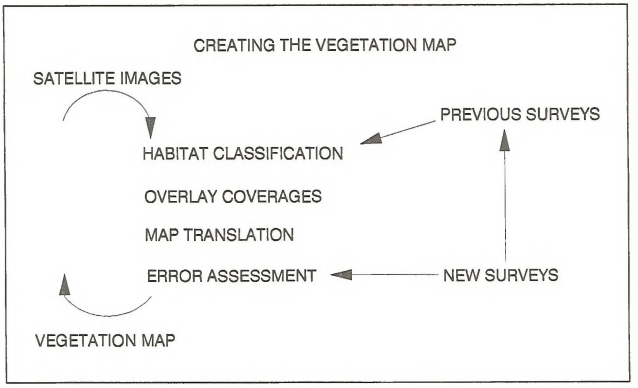

Fig. 3. Flow chart for the iterative process of developing the vegetation map from satellite imagery for the Snake River Birds of Prey Area.

from 3,027 sites sampled for percent ground cover of vegetation between 1991 and 1993. We also estimated the error in the vegetation data from south of the Snake River. The statistical error in classifying habitats was determined by posterior error rates in the linear discriminant analysis after each sample was assigned a habitat by using the PASCAL computer program and was a measure of the inherent error in creating habitat classes from continuously distributed vegetation (e.g., Whittaker 1975). We also used posterior error rates from the discriminant analysis to determine the error in the imagery used to discriminate our habitat classes. This error represented inherent error associated with classification of continuously distributed reflectance data in the image. Thus, the probability of correct translation of spectral reflectance information for a pixel into a habitat class was the product of these 2 independent probabilities.

We also determined classification accuracy from 957 points of known habitat class derived from vegetation surveys in 1993 by Study 5 of the BLM/IDARNG and randomly located throughout the study area. These points with a known habitat class were independently classified by our hierarchical method. Error rates for the test data were determined from the posterior errors in classification at both stages of the classification process. Error in the map south of the Snake River will be assessed in 1994 when independent field data are collected.

RESULTS

Habitat Classification

Our habitat classification scheme had 38 potential habitats based on percent ground cover of dominant vegetation (Table 1); 26 habitat classes were represented in our vegetation surveys with sample size ranging from 2-1,085/habitat class (Table 2). In 1993, new habitat classes were added for sites with spiny hopsage, four-winged saltbush, and little-leaf horse-brush as dominant shrub cover in addition to existing shrub classes for sagebrush, shadscale (*Atriplex confertifolia*), winterfat (*Ceratoides lanata*), greasewood (*Sarcobatus vermiculatus*), budsage (*Artemisia spinescens*), Nuttall's saltbush (*Atriplex nuttallii*), gray rabbitbrush (*Chrysothamnus nauseosus*), and green rabbitbrush (*Chrysothamnus viscidiflorus*) (Table 2). These habitats reflect inclusion of areas south of the Snake River into our vegetation maps.

The statistical error in habitat classification, estimated by posterior error probabilities in the linear discriminant analysis, was 9.3% (26 habitat classes, n = 3,027). Most classification errors were caused by medium density shrublands (class 1B) being reclassed into grasslands (class 2A or 2B) and accounted for 52% (72 of 137) of the observations misclassified between major groups (Table 3). Shrublands misclassified by density category but within the same dominant species (e.g., errors in classification between high and medium density sagebrush) represented an additional 22% of the errors.

Misclassifications in the vegetation data used for classifying the area south of the Snake River were similar to the northern data. Most errors were misclassifications of low density shrublands into grasslands (15 of 38 misclassified observations) or between density classes of shrubs (11 of 38 misclassified observations (Table 4). The error in habitat classification for the south habitat data was 8.6%.

Field personnel were far less able to correctly classify habitats than the statistical determination and were correct in 744 of 1,591 observations. Most errors resulted from incorrectly estimating percent cover of shrub groups (e.g., between 1A and 1B categories) or in classifying disturbed and grassland habitats (Table 5).

Vegetation Mapping

We used a calibration set from 1,498 samples with known habitat and spectral data to develop the quadratic discriminant function for classifying 957 samples in test data of known habitats into major grassland (classes 1D, 2A, and 2B) or shrub groups (classes 1A and 1B) based on spectral information from the 3 September 1990 and 30 March 1991 images. The posterior error rate within the calibration data was 2.4%. The misclassification rate for the test data was 23.7% and represents our error in distinguishing between grasslands and shrubs (Table 6).

Separate grassland and shrub groups were then classed into our habitat categories using the function developed from the calibration set for that group. For disturbed habitats and grasslands, the calibration data (n = 963, 9 habitats represented) had a posterior error rate of 0.9%. Habitat class 2A dominated the classification of sites (n = 576)

Table 1. Habitat classes determined from vegetation surveys on the Snake River Birds of Prey Area, 1987-92. Mean cover values of vegetation for each class are given in Table 2.

1. Shrublands

   A. High Density Shrub (Cover >25%)
      1. Sagebrush
      2. Shadscale
      3. Winterfat
      4. Greasewood
      5. Budsage
      6. Nuttall's saltbush
      7. Green rabbitbrush
      8. Gray rabbitbrush
      9. Spiny hopsage
      0. Four-winged saltbush
      a. Little-leaf horse-brush

   B. Medium Density Shrub (Cover >5% and <25%)
      1. Sagebrush
      2. Shadscale
      3. Winterfat
      4. Greasewood
      5. Budsage
      6. Nuttall's saltbush
      7. Green rabbitbrush
      8. Gray rabbitbrush
      9. Spiny hopsage
      0. Four-winged saltbush
      a. Little-leaf horse-brush

1. D. High disturbance regions
      1. Russian thistle >15%, cheatgrass >25%, native grass >25%
      2. Russian thistle >15%, cheatgrass >25%, native grass <25%
      3. Russian thistle 15-35%, cheatgrass <25%, native grass <25%
      4. Russian thistle > 35%, cheatgrass <25%, native grass <25%
      5. Russian thistle >35%, cheatgrass <25%, native grass >25%
      6. Russian thistle 15-35%, cheatgrass <25%, native grass >25%

2. Grasslands

   A. Low disturbance
      1. native perennial grasses >25%, cheatgrass <25%
      2. native perennial grasses <25%, cheatgrass <25%

   B. High disturbance
      1. Cheatgrass >25%, native grasses <25%
      2. Cheatgrass <25%, native grasses <25%

Table 2. Average percent cover of vegetation and number of samples for habitat classes in the Snake River Birds of Prey Area. Habitat classes are described in Table 1. Native grasses (NTGS) are the sum of cover values for Sandberg's bluegrass, bottlebrush squirreltail, and six-weeks fescue.

Habitat		Plant Species[a]												
Class	n	ARTR	ATCO	CELA	SAVE	ATNU	ARSP	CHNA	CHVI	GRSP	ATCA	NTGS	BRTE	SAIB
1A1	251	39										7	7	
1A2	19		32	1			1					1	1	1
1A3	40	1	1	33			1					6		
1A4	3	6			30		2			3			3	
1A5	6		3			27						12	1	3
1A6	2		2	9			20			2				
1A7	5	1						35		9		10	1	1
1A8	14								31	1		8	5	1
1B1	318	14										6	13	1
1B2	81		13				1					2	2	1
1B3	109			16								7		
1B4	2				18								1	1
1B5	16					10						8	7	14
1B6	12		2	3			11					1		1
1B7	3							11				5	21	
1B8	26								11			14	12	3
1D2	40											1	37	25
1D3	269											5	3	23
1D4	108											4	3	46
1D5	3											27	3	49
1D6	22											30	1	22
2A1	177											34	3	3
2A2	1,092											7	4	3
2B1	3											39	28	1
2B2	392											5	47	2

[a] ARTR = big sagebrush ATCO = shadscale CELA = winterfat SAVE = greasewood
ATNU = Nuttall's saltbush ARSP = bud sage CHNA = gray rabbitbrush
CHVI = green rabbitbrush GRSP = spiny hopsage ATCA = four-winged saltbush
NTGS = native grasses BRTE = cheatgrass SAIB = Russian thistle

Table 3. Error matrix for major categories of the habitat classification. Errors represent number of misclassified observations in a linear discriminant analysis of 3,027 samples and 26 habitat classes. Habitats are described in Tables 1 and 2.

Sample	Reclassified Habitat				
Habitat Class	1A	1B	1D	2A/2B	Total
1A	305	22	0	0	327
1B	15	461	9	113	598
1D	0	0	437	4	441
2A/2B	0	0	5	1,656	1,661
TOTAL	320	483	451	1,773	3,027

Table 4. Error matrix for major categories of the habitat classification in data used in classifying vegetation south of the Snake River. Errors represent number of misclassified observations in a linear discriminant analysis of 689 samples and 22 habitat classes. Habitats are described in Tables 1 and 2.

Sample	Reclassified Habitat				
Habitat Class	1A	1B	1D	2A/2B	Total
1A	67	1	0	0	68
1B	10	173	3	15	201
1D	0	0	129	9	138
2A/2B	0	0	0	282	282
TOTAL	77	174	132	306	689

in the second stage of image translation (Table 7). Separation of other habitat groups was not distinct. Errors in grassland classification include 60 shrub sites misclassified in the previous step (Table 7).

The calibration data for shrubs (n = 596, 12 habitats represented) had a posterior error rate of 1.5%. Misclassification in the test data (n = 381) included 169 grassland sites included from the previous step (Table 8). Most errors were incorrect separation of shrub densities rather than incorrect identification of shrub type.

DISCUSSION

Habitat Classification

Vegetation classifications should respond to several criteria. First, discrete communities should represent repeatable assemblages within the sample. The communities should be statistically distinguishable as well as readily recognizable by field personnel. Ideally, the classification should be robust with respect to scale of investigation. The classification also should represent major gradients in environmental variation.

Our classification scheme consisted of statistically distinct habitat categories (<10% classification errors) but was not accurately estimated in the field by trained observers. If site classification in the field is an objective, we suggest combining both density categories of shrubs. Disturbance and grassland classes also could be collapsed into fewer categories.

Vegetation Mapping

Mapping vegetation in desert rangelands from interpretation of satellite imagery has not been as successful as in forested or agricultural regions (Price et al. 1992) because sparse vegetative cover in deserts contribute little to the reflectivity perceived by the satellite (Tueller 1987). In addition to challenges created by desert environs, accuracy in creating a vegetation map depends on development of a habitat classification that has distinct categories both in field data and in the image.

Separation between shrub density categories, between low density shrubs (cover <5%) and grasslands, and between disturbance classes are errors consistent in our habitat classification, image interpretation, and field estimates.

Potential improvements in classification could be obtained by combining density classes for shrubs. In addition, both field observers and the satellite image were unable to accurately distinguish between 4 classes of grasslands and 6 disturbance classes. We suggest a recombination of these classes based on criteria of separation ability and biological importance.

PLANS FOR NEXT YEAR

We will continue to improve the habitat classification as new data become available from Study 5 of the BLM/IDARNG Research Project. In addition, we will include surveys at sites outside the Integration Study Area in our habitat classifi-

Table 5. Error matrix for estimates of habitat class by field personnel and actual habitat determined from percent cover of plant species. Underlined entries represent cells with correct classification.

Habitat Class	Field Estimated Habitat Class																	
	1A1	1A2	1A3	1A8	1B1	1B2	1B3	1B5	1B8	1D2	1D3	1D4	1D5	1D6	2A1	2A2	1B1	2B2	Total
1A1	42		2		18										2	2			66
1A2		2				6													8
1A3			8					2											10
1A5														4	1	3			8
1A8				4					6							4			14
1B1	45				45					2					9		9		110
1B2	4	6	2		4	8									2				26
1B3		2	30		1		3								2				38
1B5								4			2	2	6	2					16
1B6		4																	4
1B8				6	2				2						3	8	1	1	23
1D2					4					27		2				4		21	58
1D3					3					17	20	9	18	11	4	22		14	118
1D4				5					20	11	67	8		5	6		2		124
1D5												2	2						4
1D6										2	4	1	3		6	6			22
2A1	6				2					1		2	1	42	44	4	4		106
2A2	10	2	2		14	6	2		8	5	10	9	5	18	52	289	35	90	557
2B2	18			2	16					22					1	27	18	175	279
Total	125	16	44	12	114	20	7	4	16	93	44	95	36	45	118	424	62	316	1,591

Table 6. Error matrix of observations classed into grass or shrub categories at the first step of creating a vegetation map from satellite imagery. The calibration set consisted of 1,498 observations and had a posterior error rate of 2.4%. The test data consisted of 957 observations with known habitats. Underlined entries represent correctly classified observations.

Known Habitat Group	Classified Habitat Group		
	Grass	Shrub	Total
Grass	516	169	685
Shrub	60	212	272
Total	576	381	957

Table 7. Error matrix of observations classed into individual habitat groups after initial separation into grasslands. Underlined cells are correctly classified. The calibration set consisted of 963 observations and 9 habitat classes and had a posterior error rate of 0.9%.

Sample Habitat Class	Reclassified Habitat			
	1D	2A	2B	Total
Shrub	8	40	12	60
1D	11	47	6	64
2A	36	241	60	337
2B	14	80	21	115
TOTAL	69	408	99	576

Table 8. Error matrix of observations classed into individual habitat groups after initial separation into shrublands. Underlined cells are correctly classified. The calibration set consisted of 596 observations and 12 habitat classes and had a posterior error rate of 1.5%.

Sample	Reclassified Habitat							
Class	1A1	1A2	1A3	1A5	1B1	1B2	1B3	TOTAL
1A1	31		1		35		2	69
1A2						4		4
1A3	1		2		5	5	6	19
1A8					4			4
1B1	22				42		1	65
1B2					2	3	2	7
1B3	2		9		3	4	13	31
1B5	1				1			2
1B6					1	1		2
1B7					1			1
1B8	2				9		8	
Grass	35		1		118	12	3	169
TOTAL	94	0	13	0	218	29	27	381

cation and in creating a vegetation map for the SRBOPA.

We will try to improve the accuracy of the current vegetation map by examining the characteristics of misclassified observations. Alternate hierarchies will be examined for possible improvement in classification accuracy. We expect continued improvement as more vegetation and location data become available to better define the spectral signatures of habitat. In addition, we will try to increase samples in habitats not currently represented in the calibration data. The larger samples may permit a regional approach and should further improve the accuracy because spatial variation will be minimized.

We will complete image translation of the southern portion of the Integration Study Area. Currently, about one-half of the area is translated, including a 2-km buffer on the southern boundary. In addition, we will attempt to complete a vegetation map for the entire Snake River Birds of Prey Area in 1994.

We will use the vegetation map and satellite images for analyses of raptor foraging and prey distribution. In addition, we will examine landscape patterns, such as fractal dimensions (Milne 1988, 1992; Palmer 1992), to explain distribution and abundance of shrubsteppe passerine birds. Relationship of other species to landscape patterns also will be analyzed when data are available. Studies of landscape patterns offer potential for determining the impact of land-use practices on habitats, as well as insight into the scale at which species respond to their habitats (Wiens 1989).

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Integration Activities for the BLM/IDARNG Project

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ANNUAL SUMMARY

Principal accomplishments of the 1993 Research Project Integration effort included finalizing and implementing a protocol for constructing a burn map from satellite imagery, review of 1993 annual reports and 1994 study plans for each component study, organizing a meeting between Project personnel and BLM and IDARNG managers, and organizing a Project Integration Workshop.

OBJECTIVES

1. Provide coordination and quality control for the overall research project.
2. Develop a conceptual model that relates the impacts under study (military activities, grazing, and fire) to trophic level relationships (soils/vegetation, prey, raptors).
3. Develop and maintain the Digitized Resource Data Base Map throughout the course of the overall research project, and use it to support the field effort.
4. Provide support for analysis and preparation of documents concerning impact analysis, management, and monitoring of the SRBOPA consistent with the results of the research.

MAJOR ACCOMPLISHMENTS

Assistance in achieving the following accomplishments was provided by the staff of the Raptor Research and Technical Assistance Center of the Bureau of Land Management, particularly Steven Knick, Michael Kochert, Karen Steenhof, and Thomas Zarriello.

1. A tentative "10-year burn map" was developed by overlaying the BLM field digitized burn maps (1979-1989) on a "disturbance change-detection" map (all pixels that had been in shrub categories in 1979 but were classified into grassland or disturbed categories in 1992). We observed a general failure of other change detection methods applied to MSS satellite imagery to provide an adequate assessment of fires on a year-by-year basis.
2. Draft 1993 annual reports were reviewed for research continuity, appropriateness of analytical techniques, and possible data integration

problems. Problems identified in study details or direction were corrected, and these corrections were incorporated into the revised annual reports that appear in this volume.

3. Draft 1994 study plans were reviewed for completeness, incorporation of any necessary changes, and possible conflicts among studies. Revised versions of these plans appeared as addenda to the original study plans in the 15 January 1991 Research Plan to Assess the Impacts of Habitat Alteration in the Snake River Birds of Prey Area.

4. A meeting was held 4 March 1993 among the Management Oversight Group, BLM and IDARNG managers, and Project principal investigators, to provide a mid-project briefing on the status of the research. Project PI's provided managers with the form that management recommendations will likely take, and received suggestions from managers on how such recommendations should be presented.

5. A meeting was held 5 March 1993 consisting of all project personnel concerned with integration and analysis of data. Our principal goals were to define specific integration tasks, assign analytical responsibility for those tasks, and determine a timetable for completion of those activities. Each of these was to be accomplished in the context of the 10 basic research questions of the project and the integration modelling effort. Results of those activities were reported at the Study Integration Workshop (see below).

6. A Study Integration Workshop was held at the Bureau of Land Management Boise District Office, 16-18 November 1993. The objectives of that workshop were: (1) to present 1993 progress and 1994 plans for each of the five component studies, organized around their relationship to the principal research questions; (2) to describe the goals and progress of the integration effort, with special attention to the digitized vegetation/habitat and burn maps; (3) to present subcommittee reports resolving specific issues raised during previous workshops and meetings; (4) to discuss issues relating to the collection and analysis of grazing-related data; (5) to discuss each of the 10 principal research project questions and our analysis of data pertaining to each; (6) to discuss a variety of BLM's, IDARNG's, and other agencies' management and administrative concerns, both from their perspectives and ours; and (7) to develop a timetable for future integration activities.

PLANS FOR NEXT YEAR

1. We will continue to provide coordination and quality control in consultation with component study principal investigators and the Technical Advisory and Review Panel, include reviews of 1994 component study annual reports. We will also hold another integration workshop, nominally around 15 November 1994.

2. We will continue to develop of an overall integration model, incorporating as its basis the conceptual system model outlined in the Research Plan. The lead for overall model development would lie with the Integration staff, particularly Dr. Steven Knick, and subcontractors as appropriate, with major input and possibly submodel construction by study principal investigators (e.g., Study 4 for TGS).

3. We will continue to develop the Digitized Resource Data Base Map by adding new information as it becomes available from component studies. Additionally, we will continue development of the vegetation/habitat type map from satellite imagery to include full coverage of the SRBOPA and areas south of the Snake River.

4. We will continue to provide support for analysis and preparation of annual reports, study plans, and other documents. In addition, we will assist committees formed at the 1993 Project Integration Workshop in completing their tasks.

5. We will continue efforts to develop a common database, drawing on the experience of other large scale multi-researcher efforts (e.g., INEL, NSF-LTER's, and DOD-NERP's). Our initial focus will be on weather data, both large-scale (NOAA stations) and local (IDARNG and Project PI's).

6. We will coordinate a March 1994 meeting among Project principal investigators to develop methods for continuing biological monitoring throughout SRBOPA beyond the Project end date.

Each of the preceding activities will be assigned to one or more members of the Integration Team, who will be responsible for its timely completion. These assignments will be discussed early during the 1994 calendar year.

Prairie Falcon Post-Fledging Mortality

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ANNUAL SUMMARY

*In 1992 and 1993, we instrumented 152 prairie falcon (**Falco mexicanus**) nestlings from 27 broods with 6-g, tarsal-mounted radio transmitters and monitored their survival until they dispersed from the natal territory. Overall, 30.9% (n = 47) of fledged falcons died before dispersal (mean mortality age = 44 days, range = 32.5-69 days). Predation accounted for 48.9% of the mortalities, ectoparasite infestations were implicated in 8.5% of the mortalities, and starvation and a wing injury accounted for 4.2% of the mortalities. We could not determine the causes of 38.3% of all mortality because carcasses were scavenged and/or decomposed. Parental attendance (% time spent in the territory) and prey delivery rates (prey items delivered to the nest per hour) during late brood rearing (n = 17 broods) were not correlated with post-fledging mortality. Hatch date did not influence mortality between broods. Nestling weight at banding time was not significantly lower for males and females that died than for males and females that successfully dispersed from their natal territories. Survivorship was not correlated with brood size.*

INTRODUCTION

This is the second year of a study investigating mortality in prairie falcons during the post-fledging period. The study was initiated because the activities of birds after they fledge from their nest is 1 of the poorest known portions of avian life history (Beske 1982, Johnson 1986, Konrad and Gilmer 1986). Most studies of breeding biology stop at fledging because fledglings are mobile and difficult to follow. However, fledglings are often still dependent upon their parents for food and vigilance, and extremely vulnerable to predators, starvation, and accidents as they learn to perfect their flying skills and fend for themselves (Cade 1960). Mortality is therefore likely to be high and likely to go unnoticed at this time, and a better understanding of its magnitude and factors affecting it is needed if we are to fully understand a population's dynamics.

OBJECTIVES

1. To determine the magnitude and causes of post-fledging mortality.
2. To determine if nestling weight, parental behavior, hatch date, and brood size influence post-fledging mortality.

METHODS

Territory Selection

In 1992, we selected nesting territories being studied by the BLM/IDARNG research project based on their availability and accessibility. Unlike the 1992 breeding season, numerous prairie falcon aeries failed early in the brood-rearing period in 1993 (Marzluff et al., this volume). Therefore, as the field season progressed, we incorporated all nesting territories that had nestlings, into the study.

Field Protocol

A total of 152 nestlings from 27 territories was equipped with radio transmitters. Seventy-four nestlings in 1993 were from 10 broods west of the OTA and 8 broods within the OTA shadow (Table 1) and 78 nestlings in 1992 were from 10 broods west of the OTA and 9 broods within the OTA shadow (McFadzen and Marzluff 1992). Methods in the 1993 field season for data collection on parental behavior, radio transmitter specifications and attachment, and procedures of radio tracking fledglings, were the same as described in McFadzen and Marzluff (1992). As in 1992, we attempted to retrieve all members of a brood from the aerie, but 1 nestling from Fever Basin and 2 nestlings from Swan Road N Side could not be reached. Assignment of mortality causes for dead fledglings was expanded based on data collected in 1993 (Table 2).

Analyses

We used stepwise multiple regression analyses to test for any difference between 1992 and 1993 data. If the year effect was not significant then data were pooled and partial correlation analyses were used. These analyses held brood size constant while testing for effects of hatch date, parental attendance, and prey delivery rate on fledgling mortality. We used ANOVAs with 2 factors (mortality and year) and 2 covariates, the seventh primary (indicator of nestling age) and footpad length (indicator of nestling sex), to test for influences of nestling weight on fledgling mortality for each year. Analysis of variance also

Table 1. Number of prairie falcon nestlings equipped with radio transmitters from the 1993 territories.

Territory	Brood size	No. nestlings equipped with radio transmitters
West of OTA		
Camera	5	5
Cattleguard Gate	4	4
Falcon Flats Fingers	1	1
Fang	5	5
Guffey Rock	5	5
Mother Giant Upstream	1	1
Priest Upper	4	4
Swan Dam Draw	5	5
Swan Dam Three Poles	6	6
Swan Road N Side	5	3
Total	41	39
OTA Shadow		
Balls Pt Downstream	5	5
Cabin	5	5
CSJ Jr	5	5
Fawn Loaf	5	5
Fever Basin	4	3
Jackass NW	3	3
Powerline	5	5
Swan I Draw	4	4
Total	36	35

Table 2. Assignment of mortality causes for dead fledgling prairie falcons for 1992 and 1993.

Cause	Defining Characteristics
Avian predation	-transmitter found in raptor aerie -transmitter found in raptor pellet -fresh decapitated carcass found near owl family -owl feathers found at carcass site
Mammalian predation	-neatly buried carcass had puncture wounds and signs of internal bleeding
Starvation	-fledgling observed stranded on island until time of death
Wing injury	-fledgling found with irreparable wing injury
Ectoparasite infestation	-fledglings found dead in or below aeries heavily infested with ectoparasites
Unknown	-carcass scavenged or decomposed; only transmitter and body parts or feathers remained

was used to test for the influence of year and brood size on nestling hatch date. All percentages were transformed (arcsine of the square root) prior to analysis.

RESULTS AND DISCUSSION

Magnitude and Causes of Post-fledging Mortality

Of the 152 instrumented nestlings, 69% (n = 105) survived to disperse from their natal territories, and approximately 31% (n = 47) died before dispersal (Fig. 1). Fledgling mortality rate increased slightly from 28% (n = 22 of 78 nestlings) in 1992 to 34% in 1993 (n = 25 of 74 nestlings). Predation by great-horned owls (*Bubo virginianus*) and golden eagles (*Aquila chrysaetos*) was the major cause of fledgling mortality in both years. In 1992, avian predation accounted for 36.3% of all mortality and in 1993 it accounted for 56% of all mortality. Unlike 1992, ectoparasites belonging to the family Cimicidae were not implicated in any fledgling deaths in 1993. This year, ectoparasites infested several prairie falcon aeries early in the breeding season. These nests failed when nestlings were very young, but nesting attempts mid to late in the breeding season at other aeries appeared unaffected by these bugs. Ectoparasites were present in many of these successful nests but at levels low enough for nestlings to tolerate.

Last year, the ectoparasites were identified as Mexican chicken bugs (*Haematosiphon inodorus*) by Utah State University (U.S.U.) entomologists (A. Roe and W. Hanson). In 1993, additional specimens were collected and sent to another entomologist for identification. Dr. Teresa Morishita (University of California, Davis) identified the specimens as swallow bed bugs (*Oeciacus vicarius*). Specimens from 1993 nests will now be examined by the U.S.U. entomologists.

In 1993, we were able to document 3 new causes of fledgling mortality (Table 2) A newly fledged Fever Basin nestling was located on a river island roughly 600 vertical meters below and away from its aerie. This fledgling was observed alive with no apparent injuries in the same spot on 4 occasions. On the fifth check the nestling was found dead but not scavenged. The density of the island reeds suggests that flying out would be virtually impossible for a fledgling. Therefore, we concluded that the fledgling was physically trapped and eventually starved to death. The Jackass NW fledgling was found with a wing injury approximately 1.7 km from its natal territory. We took the bird to Dr. Pam McKinley D.V.M., who diagnosed the injury as a compound fracture. For our purposes we classified this bird as dead because the severity of injury prevented the bird from flying. At present the injured bird is in captivity. A fledgling from the Powerline territory was found neatly buried at the base of a rock outcrop in Powerline Draw. The nature of its burial suggests that it was buried by a large mammal. Upon examining the carcass we found puncture wounds and internal hemorrhaging which suggests that it was killed by a predator rather than death resulting from a collision.

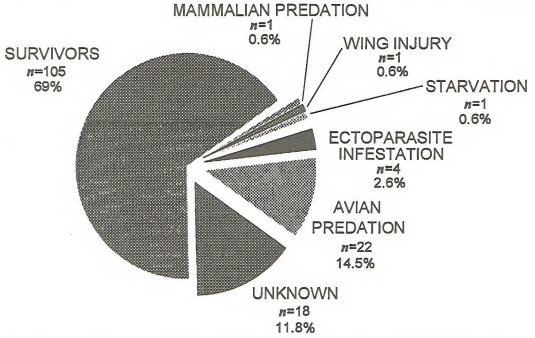

Fig. 1. Magnitude and causes of mortality for 152 prairie falcons during the post-fledging period in 1992 and 1993.

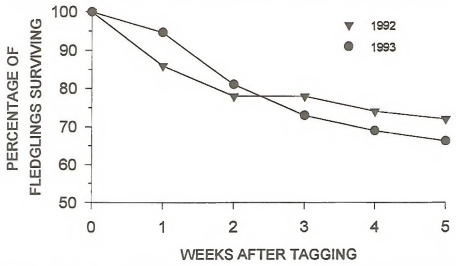

Fig. 2. Percentage of fledglings surviving from day 0 (day equipped with radio transmitter) through the post-fledging period until dispersal from the natal territory occurred during week 5 in 1992 and 1993.

For both years of the study, the causes of 18 fledgling deaths could not be identified because the carcasses were scavenged, decomposed, or no evidence could be found at a carcass site (Table 2).

Timing of Mortality

The timing of mortality during the weeks following tagging was significantly different between 1992 and 1993 (Likelihood ratio test on categories in Fig. 2 lumping weeks 3,4, and 5: $G'_{\omega} = 6.5$, $P = 0.04$). In 1992, half of all mortality occurred during the first week after tagging. These young died before reaching fledging age. In contrast, only 5% of mortality occurred during this time in 1993. The largest decline in survivorship in 1993 happened during the second week post-tagging. Forty percent of the mortality occurred during this time. The abrupt decline during the first week after tagging in 1992 included nestlings that died from the influence of ectoparasite infestations. These nestlings died at a significantly younger age than nestlings that died from avian predation (McFadzen and Marzluff 1992). The percentage of fledglings surviving remained stable during the third week post-tagging for the 1992 fledglings but decreased by 8% for the 1993 fledglings. For the next 2 weeks the number of individuals dying was relatively low and similar for both years. By the fifth week, 69% of the 152 fledglings survived to disperse from their natal territories. Mean dispersal age was not significantly different for females in 1992 (mean = 66.8 days, SD = 4.4, n = 29) versus females in 1993 (mean = 65 days, SD = 4.4, n = 27; $F_{1,54} = 1.27$, $P = 0.27$) or for males in 1992 (mean = 64.6 days, SD = 4.5, n = 27) versus males in 1993 (mean = 63.6 days, SD = 4.5, n = 22; $F_{1,47} = 0.99$, $P = 0.32$).

Factors That May Influence Post-fledging Mortality

Nestling weight.—Nestling weight at tagging (age approximately 30 days old) did not influence subsequent survival for males or females during the post-fledging period in 1992 and 1993. The seventh primary and footpad length were significant covariates in analysis of nestling weight. We reanalyzed the 1992 data using these covariates and found that nestling weight for males and for females was not statistically different between those that died (males: adjusted mean = 543.5 g, SD = 34.3, n = 11; females: adjusted mean = 800.4 g, SD = 64.5, n = 11) and those that survived (males: adjusted mean = 542.8 g, SD = 33.9, n = 27; females: adjusted mean = 785.3 g, SD = 61.4, n = 29) (males: $F_{1,34} = 0.00$, $P = 0.98$; females: $F_{1,34} = 0.39$, $P = 0.53$). Analysis of the 1993 data also showed that nestling weight did not differ between males that survived (adjusted mean = 563.8 g, SD = 23.9, n = 21) and those that died (adjusted mean = 557.5 g, SD = 24.4, n = 8; $F_{1,25} = 0.38$, $P = 0.55$) or between females that survived (adjusted mean = 800.2 g, SD = 40.8, n = 27) and those that died (adjusted

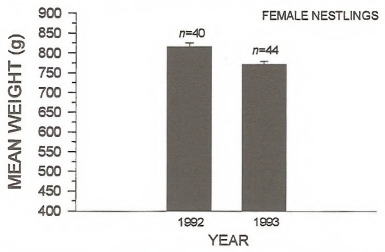

Fig. 3. The relationship between nestling weight for females in 1992 and for females in 1993. Mean nestling weight was adjusted for seventh primary and toe pad (+ 1 SE).

mean = 784.7 g, SD = 41.5, n = 17; $F_{1,40}$ = 1.37, P = 0.25). Nestling weights of males in 1992 (adjusted mean = 559.2 g, SD = 40.5, n = 38) did not differ from those in 1993 (adjusted mean = 541.5 g, SD = 40.6, n = 29; $F_{1,61}$ = 2.48, P = 0.12). Pooled data for both years showed that nestling weights of males that died (adjusted mean = 551.07 g, SD = 32.0, n = 19) were similar to nestling weights of males that successfully dispersed (adjusted mean = 549.65 g, SD = 32.2, n = 48; $F_{1,61}$ = 0.26, P = 0.87). Nestling weights of females from the 1992 nests (adjusted mean = 815.5 g, SD = 62.9, n = 40) were significantly higher than nestling weights of females from 1993 nests (adjusted mean = 770.9 g, SD = 54.0, n = 44; $F_{1,78}$ = 10.6, P = 0.002: Fig. 3). We investigated the difference in weights of nestling females between years and found that nestlings in 1992 were measured at a younger age (mean = 29.7 days old, SD = 1.7, n = 19 broods) than nestlings in 1993 (mean = 31.5 days old, SD = 1.7, n = 18 broods; $F_{1,35}$ = 11.26, P = 0.002). However, nestling weight of males did not differ between years. Therefore, some other factor may have caused the variation in female nestling weight in 1992 and 1993. Nestling weight was not a good indicator of subsequent survival in this study primarily because predation was the major cause of mortality; fledglings were preyed upon regardless of their weight at tagging.

Parental behavior.—As in 1992, we found that in 1993, parental behavior during the late brood-rearing period (nestling age 21-40 days old) was not significantly correlated with post-fledging mortality. We found no relationship between the amount of time an adult spent in the territory and brood mortality (males: r = -0.09, P > 0.50, n = 6 broods; females: r = -0.31, P >0.50, n = 6 broods). The hourly rate of prey deliveries to the nest by parents (male and female total) also was not correlated with brood mortality in 1993 (r = -0.74, P > 0.10, n = 6 broods). Data were pooled between years because stepwise multiple regression yielded no significant interactions between brood size, male and female attendance rates, total prey delivery rates, and year on the percentage of brood mortality (all P values > 0.36). Partial correlation analysis of pooled data showed that parental attendance and prey delivery rates were negatively correlated with the percentage of the brood dying but not significantly (male attendance: r = -0.06, P > 0.50, n = 17 broods, [Fig. 4]; female attendance: r = -0.09, P >0.50, n = 17 broods, [Fig. 4]; total prey delivery rate: r = -0.25, P > 0.20, n = 17, [Fig. 5]). Our measures of parental care during the late brood rearing period apparently had little influence on subsequent fledgling survivorship. Although parents are providing adequate food and vigilance to their nestlings, it is apparent that they cannot defend their young against nocturnal predation by great-horned owls.

Hatch date.—In 1992, fledglings that died had hatch dates that were later in the breeding season than fledglings that survived. We reanalyzed last year's data using a partial correlation with the brood as the sampling unit and holding brood size constant. We found that the mean hatch date of fledglings within a brood had no influence on the percentage of the brood that died (r = 0.27, P > 0.20, n = 19). Analysis of 1993's data showed similar results; broods hatching early in the season did not experience lower brood mortality than those hatching late (r = 0.32, P > 0.10, n = 18). Stepwise multiple regression analysis showed no influence of brood size and mean hatch date on the percentage of the brood dying between years (all P values > 0.09). Partial correlation analysis on both years of data combined revealed that higher brood mortality was mildly correlated with a late mean hatch date (r = 0.30, P < 0.10, n = 37; Fig. 6). In 1993, hatch date (mean day of the year = 122.0, SD = 8.1) for broods of 5 nestlings (n = 10) was not significantly earlier than hatch dates (mean day of the year = 127.8, SD = 2.7) for broods of 4 nestlings (n = 4; $F_{1,12}$ = 1.65, P = 0.22) as it was in 1992 ($F_{1,14}$ = 8.98, P = 0.01). We analyzed both years of data and found no significant interaction between year and brood size ($F_{1,26}$ = 1.80, P = 0.19) and no significant year effect on hatch date ($F_{1,26}$ = 2.42, P = 0.13). However, broods of 5 nestlings (n = 18) had significantly earlier mean hatch dates (mean day of the year = 117.5, SD = 2.1, n = 18) than broods of 4 nestlings (mean day of the year = 127.3, SD = 10.6, n = 12) ($F_{1,26}$ = 8.93, P = 0.01). The influence of brood size on hatch date in 1992 was not evident in 1993. This probably reflects our sample of very few early hatched nests because of nest failure early in the 1993 breeding season. Hatch dates spanned a range of 39 days in 1992 whereas hatch dates spanned a range of 26 days in 1993. The influence of mean hatch date on brood mortality also may have been more accentuated if early hatching nests had not failed.

It is difficult to ascertain why fledglings with late hatch dates would be more susceptible to avian

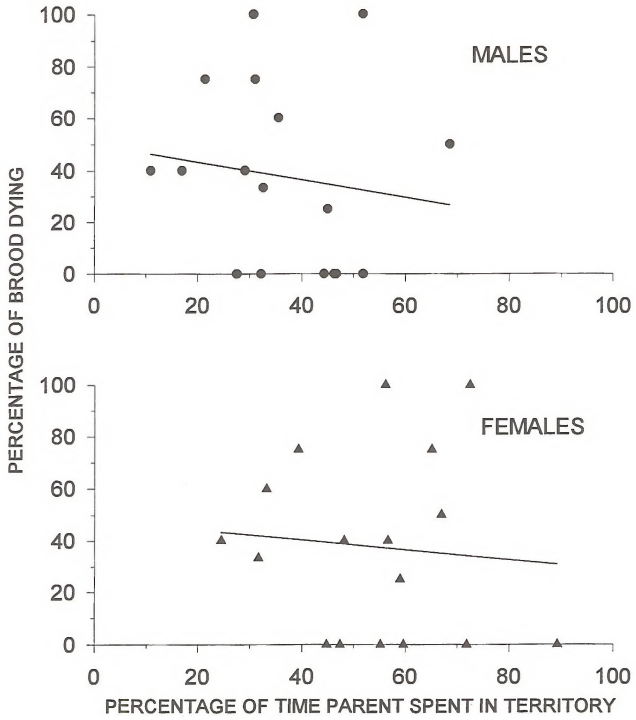

Fig. 4. Partial correlations between male and female parental attendance during the late brood rearing period (nestling age 21-40) and the percentage of their broods dying post-fledging, holding brood size constant, in 1992 and 1993.

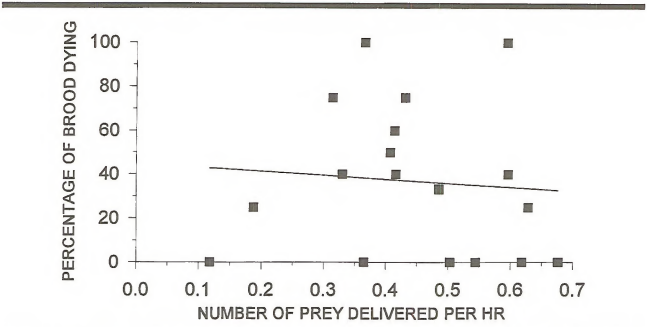

Fig. 5. Partial correlation between prey delivery rates made by both parents during the late brood rearing period (nestling age 21-40) and the percentage of their broods dying post-fledging, holding brood size constant, in 1992 and 1993.

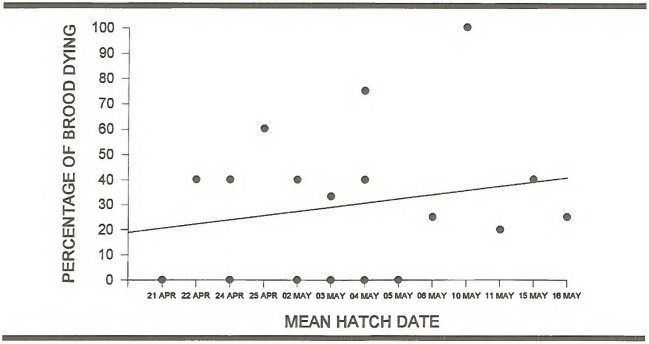

Fig. 6. Partial correlation between mean hatch date per brood and percentage of brood dying, holding brood size constant, in 1992 and 1993.

predation, primarily by great-horned owls. General health of these late hatched birds may deteriorate because of declining prey late in the season, thus making them more vulnerable to predators. But it is more likely that the success of great-horned owl predation is influenced by a combination of fledgling inexperience and the owls' foraging strategies.

Brood size.—Brood size at 80% of fledging age did not influence the number of individuals that died within a brood in 1993 ($F_{1,11} = 1.08$, $P = 0.414$, $n = 16$ broods) or in 1992. Analysis of pooled data for both years yielded the same results; brood size did not significantly influence the degree of mortality within a brood ($F_{3,28} = 1.03$, $P = 0.42$, $n = 32$ broods; Fig. 7). However, nests fledging large broods did produce more survivors than those fledging small broods. Pooled data for 1992 and 1993 showed that brood size at 80% of fledging age was significantly correlated with the number of fledglings dispersing from a territory ($r = 0.80$, $P < 0.001$, $n = 54$; Fig. 8). However, there was considerable scatter in this relationship, and caution should be applied in interpretations of brood size as a measure of productivity. Brood sizes of 3, 4, and 5 produced significantly more disperses than did broods of 0, 1, and 2 ($F_{4,30} = 3.73$, $P = 0.013$). Pairwise comparisons revealed no significant differences in post-fledging productivity between all brood sizes (all P values > 0.05).

Fledgling Locations Beyond the Natal Territory

We collected information on locations of fledglings beyond their natal territories in 1993. The radio signals of 21 individuals from 12 broods were detected after they dispersed from their natal territories. In 1992, fledgling signal locations were concentrated between Initial Point and the northwest corner of the Range Road (McFadzen and Marzluff 1992). This year a greater effort was made to detect signals, but fewer were detected and locations were scattered (Fig. 9). The difference in the results for 1992 and 1993 may reflect the decrease in the abundance of Townsend's ground squirrels (*Spermophilus townsendii*; Van Horne et al., this volume), the primary food source of prairie falcons at the Snake River Birds of Prey Area.

ACKNOWLEDGMENTS

This project was supported by the U.S. Army Chemical Research, Development, and Engineering Center, Greenfalk Consultants, and the BLM Raptor Research and Technical Assistance Center. We thank all of the Greenfalk field and office staff for their excellent assistance. Special thanks to Nicole DiLuglio and Marty Miller for their dedicated and relentless pursuit of prairie falcon fledglings. Thanks to Bryan Kimsey, Linda Schueck and Mark Vekasy of Greenfalk Consultants, and Scott Harris, Robert Hogan and Bob Lehman of the BLM for their climbing expertise. Thanks to Dr. Pam McKinley for examining an injured fledgling and to James McKinley for providing care to the bird. We also thank the following individuals at the BLM Raptor Research and Technical Assistance Center for their assistance: Leslie Carpenter and Dave Dyer for vehicle support, Deanna Dyer for map making, and Mike Kochert and Karen Steenhof for editorial comments.

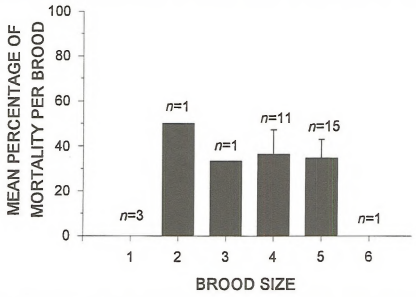

Fig. 7. Mean percentage (+ 1 SE) of mortality per brood compared with brood size at banding time in 1992 and 1993.

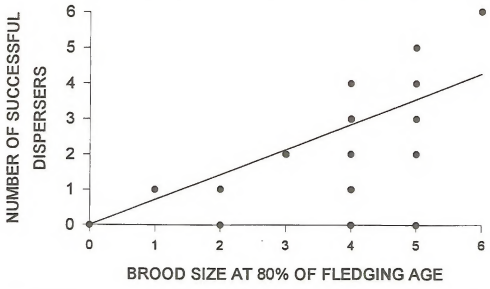

Fig. 8. Pearson correlation between the number of fledglings that successfully dispersed from the natal territory and brood size when nestlings were 80% of fledgling age in 1992 and 1993.

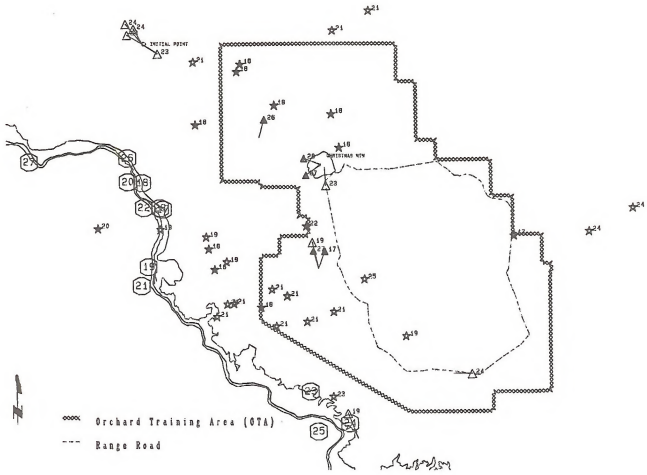

Fig. 9. Locations of fledglings beyond their natal territories in 1993. Filled symbols indicate locations for fledglings hatched west of the OTA and open symbols indicate locations for fledglings hatched inside the OTA shadow. Stars indicate point estimates obtained by visual observations, or triangulation. Triangles are locations from which bearings were taken toward fledglings. Direction of the fledglings' signals from the triangle is indicated by the line out of the symbol. Octogons indicate aerie locations. Numbers associated with fledgling bearings indicate the natal aerie.

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Appendix A. Leg band combinations, radio frequencies, and mortality causes of prairie falcon fledglings that died during the post-fledging period in 1993.

		Leg Bands		
Territory	Frequency	Alpha-Numeric	USFWS	Mortality Cause[a]
West of OTA				
CAMERA	165.145	4/H	2206-22890	unknown
CATTLEGUARD GATE	165.524	4/G	2206-22889	predation
CATTLEGUARD GATE	165.547	E/G	1807-41441	predation
CATTLEGUARD GATE	165.596	E/H	1807-41442	predation
FANG	165.104	D/D	1807-41419	predation
FANG	165.118	D/B	1807-38550	predation
FANG	165.424	D/C	1807-38549	predation
SWAN ROAD NS	165.235	G/6	1807-47805	predation
SWAN ROAD NS	165.257	7/V	816-74843	predation
SWAN DAM DRAW	165.645	E/4	1807-01326	unknown
SWAN DAM DRAW	165.773	5/V	816-74641	unknown
OTA Shadow				
BALLS POINT DS	165.625	5/D	816-74630	predation
BALLS POINT DS	165.714	R/3	1807-01315	unknown
CSJ JR	165.165	E/A	1807-41436	unknown
CSJ JR	165.185	3/Y	2206-22882	unknown
FAWN LOAF	165.006	E/P	1807-41446	predation
FAWN LOAF	165.015	E/N	1807-41445	predation
FAWN LOAF	165.035	E/M	1807-41444	predation
FAWN LOAF	165.048	3/T	2206-22876	predation
FAWN LOAF	165.095	3/S	2206-22875	predation
FEVER BASIN	165.375	B/7	1807-47813	starvation
JACKASS NW	165.326	D/T	1807-41429	wing injury[c]
POWERLINE	165.383	D/Y	1807-41434	unknown
POWERLINE	165.685	D/V	1807-41431	predation[c]
SWAN I DRAW	165.315	D/4	1807-01325	unknown

[a]Mortality Cause
predation=death was caused by a golden eagle or a great-horned owl
unknown=cause of death could not be determined
[b]death probably caused by a large mammal
[c]taken into captivity due to irreparable wing injury

Use of Nest Boxes by American Kestrels In Southwestern Idaho

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ANNUAL SUMMARY

*American kestrels (**Falco sparverius**) nested in 16 boxes along I-84 and near Kuna, Idaho in 1993. Occupancy rates (33%) were lower than all years except 1986 and 1989, but nesting success rates (81%) were the second highest recorded during the 8-year study.*

OBJECTIVES

1. Determine kestrel occupancy rates and nesting success at boxes erected in southwestern Idaho.
2. Mark nestling and adult kestrels to accumulate baseline data for future studies on dispersal and population dynamics.

INTRODUCTION

This study began in 1985 when nest boxes were erected on abandoned power poles in the Snake River Birds of Prey Area in an effort to learn more about the food habits and breeding biology of American kestrels in southwestern Idaho (Steenhof et al. 1985). The limited use of those boxes prompted curiosity about factors that influence occupancy rates. In 1986, the Idaho Fish and Game Department's Nongame program joined the study, and the study area expanded to include agricultural and suburban habitat in the Kuna area as well as Interstate 84 between Simco Road and Caldwell. From 1989 to 1993, BLM had sole responsibility for monitoring the boxes.

METHODS

Boxes have been erected for kestrels in 3 separate study areas in southwestern Idaho: on trees within agricultural habitat in the vicinity of Kuna, Idaho (hereafter referred to as the Kuna Route); on highway signs along Interstate 84 between Simco Road and Caldwell (hereafter referred to as the I-84 route); and on abandoned power poles along the north rim of the Snake River Canyon (hereafter referred to as the BOPA route). Monitoring in 1991 focused on the boxes on the Kuna and I-84 routes because of high vandalism and low kestrel occupancy rates on the BOPA route (Steenhof 1989). In 1993, 27 boxes were available on the I-84 route, and 22 were available on the Kuna route. Several boxes on both routes have been destroyed since the study began. One new box was put up in 1993 on the Kuna route.

All boxes were checked in March, and we cleaned boxes and added shavings at that time. All boxes on the Kuna route and I-84 route were checked again in late April, and boxes with viable nesting attempts were re-visited from May through July as necessary to band young and ascertain nesting

success. Nests with young that could be sexed (75% feathered: approximately 22 days; Griggs and Steenhof 1983) were considered successful. Investigators checked boxes while standing on a ladder. When checking boxes, investigators inserted a hole stuffer into the nest box entrance to trap any adult birds in the box. Adults and young were weighed with a 300-g Pesola balance. Nests of European starlings (*Sturnus vulgaris*) were removed in an effort to keep all boxes suitable for kestrel nesting.

In 1993, we initiated a new investigation of breeding site fidelity and attempted to capture all adults using the boxes. Boise State University undergraduate student, Michelle Drysdale, used a bal-chatri to capture kestrels from February through April (see Drysdale, this volume). During the brood-rearing season, we used mist nets placed directly in front of nest boxes, with a live great horned owl (*Bubo virginianus*) tethered behind the nets.

RESULTS

Sixteen (33%) of 49 available boxes on the Kuna and I-84 routes were used for nesting by kestrels in 1993. The 1993 box occupancy rate was lower than all years except 1986 and 1989. (Table 1).

Occupancy rates on the I-84 and Kuna routes were similar in 1993 (33% and 32%) The number of boxes occupied by kestrels on the Kuna route decreased from 13 in 1992 to 7 in 1993, and the number of occupied I-84 boxes decreased from 10 to 9. Although the number of boxes used on I-84 has been relatively stable, different boxes have been used each year; only 5 of the 9 boxes used in 1993 had been used in 1992. One had been used in 1991, 1 was last used in 1989, and 2 were used for the first time in 1993.

In contrast, 6 of 7 boxes used by kestrels in 1993 on the Kuna route had been used in 1992. The seventh was last used in 1991.

Overall nesting success of 16 kestrel pairs in 1993 was 80%, well above the 8-year average of 64% (Table 2). Seventy-eight percent of I-84 nests were successful, and 86% of nests on the Kuna route were successful. Five of 13 successful nests had at least 1 egg that failed to hatch, and nestlings died at 3 successful boxes. Observed clutch sizes ranged from 2 to 6 in 1993; clutch size was 5 in 8 of 15 cases, and 4 in 5 others. We observed 1 brood of 6 for the fifth consecutive year.

We captured 23 of the 32 breeding adults at the 16 occupied boxes on the Kuna and I-84 routes in 1993. Four of the 23 kestrels were caught prior to the breeding season in bal-chatri traps, 13 were caught in boxes, and 6 were caught in mist nets (Table 3). The bal-chatri was the least effective technique because it captured the fewest territorial adults and because we had to recapture birds to verify that they were 1 of the adults associated with the nest box. We caught 81% of the females in boxes during nest checks, but only 19% of the males were captured in boxes. The mist-netting technique was more effective in catching males: we caught males at 6 of the 9 boxes where we set mist nets. Overall, 38% of the males were captured in mist nets. Of the 9 breeding adults we failed to catch (7 males, 2 females), 4 (3 males, 1 female) were associated with nesting attempts that failed during incubation.

Table 1. Occupancy rates of kestrel boxes on the Kuna and I-84 routes, 1986-1993. Number of available boxes in parentheses.

Year	I-84	Kuna	Overall
1986	24% (17)	18% (17)	21% (34)
1987	41% (32)	39% (31)	40% (63)
1988	30% (30)	40% (30)	35% (60)
1989	28% (29)	27% (30)	27% (59)
1990	36% (28)	38% (26)	37% (54)
1991	36% (28)	58% (24)	46% (52)
1992	36% (28)	59% (22)	46% (50)
1993	33% (27)	32% (22)	33% (49)
$\bar{x}$	33%	39%	36%

Table 2.Percent of kestrel nests successful on the Kuna and I-84 routes, 1986-1992. Sample sizes in parentheses.

Year	I-84	Kuna	Overall
1986	0% (3)	0% (4)	57% (7)
1987	54% (13)	55% (11)	54% (24)
1988	44% (9)	50% (12)	48% (21)
1989	25% (8)	75% (8)	50% (16)
1990	80% (10)	89% (9)	84% (19)
1991	70% (10)	64% (14)	67% (24)
1992	60% (10)	77% (13)	70% (23)
1993	78% (9)	86% (7)	81% (16)
$\bar{x}$	51%	75%	64%

Table 3. Number of adult American kestrels captured using 3 techniques in the Kuna and I-84 study areas, 1993.

Method of Capture	Territorial Female	Territorial Male
Bal-chatri	3	1
Caught in Box	13[a]	3
Mist Net/Great Horned Owl	3[b]	6[c]

[a] includes 3 adult females caught earlier in 1993 in a bal-chatri
[b] includes 2 adult females caught earlier in 1993 (1 in a box; 1 in a bal-chatri)
[c] includes 1 adult male caught earlier in 1993 in a bal-chatri

We banded 61 kestrels in or near boxes along the 2 routes in 1993 (44 nestlings and 17 adults). We also recaptured 3 kestrels at boxes where they had been banded as adults in previous years. The female at I-84 #11 had nested in the same box in 1990 and 1991. A different female had used the box in 1992. At Kuna #110, both the female and the male were returnees: the female was banded at the box in 1992, and the male was banded there in 1991. We did not capture a male at Kuna #110 in 1992. Additional information on site fidelity of kestrels is reported by Drysdale (this volume).

Although none of the kestrels we captured had been banded as nestlings, George Carpenter caught a female we had banded as a nestling at I-84 #30 in 1992. The bird bred successfully in 1 of Carpenter's boxes, 10.7 km from its natal box.

We caught a female in I-84 #8 that had been banded in September 1989 in the Goshutes Mountains, Nevada. We found no evidence that this bird laid eggs in 1993.

PLANS FOR NEXT YEAR

Monitoring of occupancy and reproduction will continue in 1994 and will expand to include boxes erected by George Carpenter. We will attempt to capture and identify all breeding adults, particularly those at boxes where adults were caught in 1993.

ACKNOWLEDGMENTS

This study could not have been completed without the assistance of George Carpenter, Jim Bednarz, and Michelle Drysdale. Deana Parrish, Deanna Dyer, and Barbara Stuart also assisted with field work. We are especially indebted to the landowners in the Kuna area who graciously allowed us to set up and check boxes on their property. The National Geographic Society donated a ladder to the study.

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Effects of Food Availability and Disturbance on Nesting American Kestrels in Southwestern Idaho

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ANNUAL SUMMARY

*American kestrels (**Falco sparverius**) nesting in boxes were monitored in 1992-93 near Kuna, Idaho. Some kestrels were supplementally fed and disturbed frequently, some were not fed but were disturbed frequently, and others were not fed or frequently disturbed. Resulting reproductive variables indicated that disturbance delayed breeding, reduced clutch size, and reduced breeding success in 1993 but not in 1992. Also, food supplementation reduced the disturbance effects in 1993. Kestrels may tolerate frequent human disturbance in some years but not others. Food stressed kestrels may be more sensitive to human disturbance than better fed birds.*

OBJECTIVES

1. Test the effects of food availability on reproductive performance.
2. Test the effects of frequent disturbance on reproductive performance.

INTRODUCTION

In 1993, I completed a 2-year study that tested offspring sex ratio hypotheses with American kestrels near Kuna, Idaho (Carpenter 1992). The study design made it possible to address 2 additional questions: (1) How does food availability affect kestrel reproductive performance; and (2) how does frequent disturbance affect kestrel breeding performance?

Data analysis involving sex ratio hypotheses has not been completed, so this report focuses on the effects of food availability and disturbance on reproductive performance.

METHODS

In 1992 and 1993, the Bureau of Land Management (BLM) staff of the Raptor Research Technical Assistance Center, 3 Boise State University (BSU) student assistants, and I monitored 126 available nest boxes in 2 adjacent study areas near Kuna, Idaho. Fifty boxes were in Study Area A (those in the Kuna and I-84 Routes as described by Steenhof, this volume), and 76 boxes were in study area B. Most Area A boxes are mounted on trees or highway signs and have been present since 1986 (Steenhof, this volume), but Area B boxes were erected on 2 X 4 boards in February 1992.

Box occupancy was confirmed when a kestrel pair was observed within 400 m of a box that was defended or had a nest bowl formed inside. Any box occupied by a pair of kestrels was assigned 1 of 3 treatment combinations in an attempt to create food availability and investigator disturbance

Table 1. Experimental treatment combinations for occupied American kestrel nest boxes in southwestern Idaho, 1992-93.

Treatment		Number of nests	
Food	Disturbance	1992	1993
Fed	disturbed	15	21
Not fed	disturbed	19	26
Not fed	not disturbed	31	21

disparities (Table 1). Boxes that were fed and disturbed or fed and not disturbed were chosen randomly in Study Area B, but all occupied boxes in Study Area A received the not-fed and not-disturbed combination. Seven Area B boxes in 1992 and 5 Area B boxes in 1993 were also not fed and not disturbed, because they were not identified as occupied until after egg laying was completed.

At sites that were fed and disturbed we left dead Japanese quail or house mice 3 to 4 times a week from occupancy to desertion or fledging. We left supplemental food in vinyl tubes mounted on the box supports (Carpenter 1992). At sites that were not fed and disturbed we approached but only simulated leaving food. All disturbed sites were visited every day or every other day during laying, hatching, and fledging periods to note eggs or young, and chicks were measured 3 times a week from hatching to fledging. However, we deviated from this schedule in 1993, as frequent visits during egg laying were discontinued due to several early abandonments of boxes with incomplete clutches. In total, successful pairs receiving the first 2 treatment combinations were disturbed 40 to 50 times from occupancy to fledging for approximately 1- to 40-min periods.

The not-fed and not-disturbed sites were visited only 2 to 6 times from occupancy to fledging for approximately 1- to 40-min at a time (for Study Area A details, see Steenhof, this volume). Therefore, the not-disturbed sites were disturbed at approximately 10% of the frequency of the disturbed sites.

Ten reproductive variables were analyzed (Appendix A). Values for the variables were compared by food treatment, disturbance treatment, and year. Contingency Table Analysis was used to evaluate categorical variables, and 3-way ANOVA was used to evaluate non-categorical variables.

For 3 variables (median hatching date, clutch size, and productivity) I considered experimental treatments effective if they were initiated at least 8 days prior to egg laying. Therefore, sites where treatments were not initiated at least 8 days prior to the appearance of the first egg were considered not fed and not disturbed.

RESULTS AND DISCUSSION

Box Use and Banding

Nest box use and banding data for Study Area A are reported by Steenhof (1992, and this volume). Thirty-seven (49%) and 46 (61%) boxes in Area B were occupied at least once in 1992 and 1993, respectively. Combining study areas, kestrels occupied 62 boxes (49% of 162 available) at least once each year. In 1992, 3 boxes were occupied twice, and in 1993, 6 boxes were occupied twice.

Fifteen (45%) of 33 breeding attempts were successful in Study Area B in 1993. Kestrels abandoned 15 boxes with incomplete (not incubated) clutches. Three incubated clutches did not hatch. A single chick died in 1 box, and 2 chicks died in another box. We banded 116 kestrels in or near Study Area B in winter, spring, and summer 1993. Twenty-three of these birds were adult males, 35 were adult females, 28 were nestling males, and 30 were nestling females.

Food Availability, Disturbance and Reproductive Performance

Overall reproduction of the kestrels is summarized in Appendix B.

There was no evidence that food treatment, disturbance treatment, or year affected egg abandonment (Contingency Table Analysis G-test: $P = 0.167$ $df = 5$ $n = 103$), hatching success

(Contingency Table Analysis: $P = 0.122$ df = 5 $n = 79$), hatchability (ANOVA: $P = 0.082$ df = 69) nestling survivorship (Contingency Table Analysis: G-test $P = 0.668$ df = 5 $n = 62$), or fledging condition (ANOVA: males $P = 0.560$ df = 42, females $P = 0.215$ df = 44).

Kestrels bred later in 1993, bred later when disturbed, and there was an interaction between food treatment, disturbance treatment, and year (ANOVA: $P = 0.015$ df = 77; Table 2). Disturbed pairs often bred 2 to 4 weeks later than less disturbed pairs in 1993 but not in 1992, and supplemental feeding may have partially reduced the delay in 1993 (Fig. 1). This pattern may have been affected by birds renesting in 1993. Several early-laying pairs abandoned incomplete clutches in 1993, but early egg abandonment was rarely observed the previous year.

Occupied pairs that were not fed and disturbed laid eggs less often than expected in 1993. The same was true for 1993 fed and disturbed pairs, but to a lesser extent (Contingency Table Analysis G-test: $P = 0.046$ df = 5 $n = 81$). This indicates that food supplementation may have buffered the effect of investigator disturbance in 1993.

Clutch size was significantly lower in 1993 than 1992. Clutch size decreased more for not-fed and disturbed sites than the other 2 treatment combinations, indicating that clutch size may have been affected by disturbance and food availability (ANOVA: $P = 0.000$ df = 77; Table 3, Fig. 2).

Breeding success may not have been independent of food and disturbance treatments and year (Contingency Table Analysis G-test: $P = 0.050$ df = 5 $n = 108$). The major contributors to the G-statistic were 1993 not-fed and disturbed sites. Pairs in this group were less likely to produce at least 1 24-day-old chick than expected. This indicates that 1993 breeding success was reduced by disturbance and that food supplementation buffered the effect.

Table 2. Results of ANOVA for effects of food treatment, disturbance treatment, and year on median hatching date[a] of American kestrels in southwestern Idaho, 1992-93.

Source	R^2	P^b
Food[c]	0.009	0.250
Disturbance[d]	0.035	0.025
Year	0.061	0.003
Food * Disturbance * Year	0.069	0.008
Model	0.174	0.015

[a] Median observed or estimated hatching dates of clutches.
[b] df = 77.
[c] Food supplemented sites compared with not-supplemented sites.
[d] Disturbed sites compared with not-disturbed sites.

Table 3. Results of ANOVA for the effects of food treatment, disturbance treatment, and year on clutch size in American kestrels in southwestern Idaho, 1992-93.

Source	R^2	P^a
Food[b]	0.029	0.060
Disturbance[c]	0.019	0.135
Year	0.163	0.000
Food * Disturbance * Year	0.059	0.032
Model	0.273	0.000

[a] df = 77.
[b] Food supplemented sites compared with not-supplemented sites.
[c] Disturbed sites compared with not-disturbed sites.

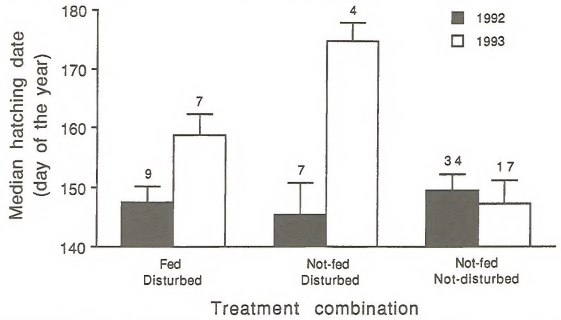

Fig. 1. Median hatching dates (+ 1 SE) of American kestrel clutches in southwestern Idaho by treatment combination and year. Numbers above bars are sample sizes.

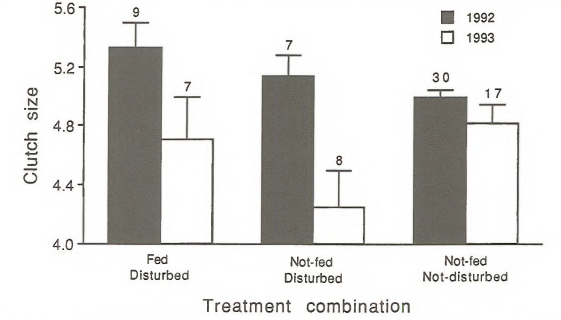

Fig. 2. Clutch size (+ 1 SE) of American kestrels in southwestern Idaho by treatment combination and year. Numbers above bars are sample sizes.

Productivity declined from 1992 to 1993 (ANOVA: $P = 0.016$ df = 70). Productivity results reflected clutch size data because hatchability showed no significant pattern, and nestling survivorship was uniformly high. For productivity, however, there was no significant interaction between year and treatment (Table 4, Fig. 3). Therefore, we found no evidence that food treatment or disturbance influenced productivity.

In summary, median hatching date, egg laying, clutch size, and breeding success were affected by investigator disturbance in 1993. These effects were probably buffered by food supplementation. We found no evidence that egg abandonment, hatching success, hatchability, productivity, fledging condition, or nestling survivorship were affected by disturbance or food treatment.

Why did reproductive performance decline from 1992 to 1993? Decreased reproductive performance in the kestrels featured delayed breeding, reduced clutch size, and decreased breeding success. These same variable responses were linked to food shortages in Eurasian kestrels (*F. tinnunculus*; Meijer 1988, Village 1990). Our evidence

Table 4. Results of ANOVA for the effects of food treatment, disturbance treatment, and year on productivity[a] in American kestrels in southwestern Idaho, 1992-93.

Source	R^2	P^b
Food[c]	0.023	0.226
Disturbance[d]	0.000	0.865
Year	0.138	0.004
Food * Disturbance * Year	0.027	0.412
Model	0.189	0.016

[a] Number of chicks that survived to at least 24 days of age at hatching successful sites.
[b] df = 70.
[c] Food supplemented sites compared with not-supplemented sites.
[d] Disturbed sites compared with not-disturbed sites.

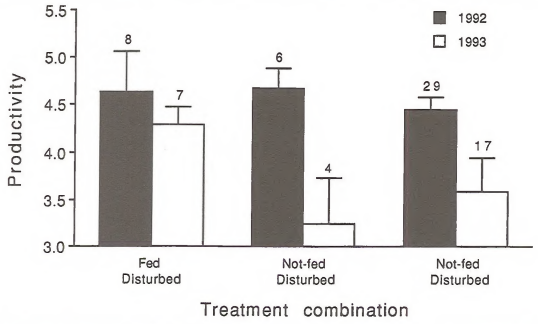

Fig. 3. Productivity (+ 1 SE) of American kestrels in southwestern Idaho. Data are numbers of fledglings per site where at least 1 chick hatched. Numbers above bars are sample sizes.

that supplemental feeding buffered the decline in reproductive performance indicates that kestrels were more energetically stressed the second year of this study. Swainson's hawks (*Buteo swainsoni*) in the same area showed a similar decline in reproductive performance from 1992 to 1993 (M. Bechard, Boise State Univ., pers. commun.). Because Swainson's hawks have a high degree of prey overlap with kestrels (M. Bechard, Boise State Univ., pers. commun.; Johnson et al. 1987), prey-related causes may be likely. Therefore, quality or quantity of prey may have declined during the study and caused decreased reproductive performance.

The results indicate that American kestrels may tolerate frequent human disturbance in some years but not others. Evidence that supplemental feeding buffered reproductive performance declines indicates that food stressed kestrels may be more sensitive to human disturbance than better fed birds.

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Appendix A. Definitions of reproductive variables for American kestrels in southwestern Idaho, 1992-93.

Variable	Definition
Median hatching date	Median observed or estimated hatching dates of clutches.
Egg laying	Whether or not an occupied pair laid at least 1 egg. Fed and disturbed or not-fed and disturbed sites only.
Clutch size	Number of eggs in incubated clutches.
Egg abandonment	Whether or not eggs were abandoned prior to or during incubation.
Hatching success	Whether or not at least 1 egg hatched in incubated clutches.
Hatchability	Proportion of eggs hatched in incubated clutches.
Breeding success	Whether or not at least 1 chick survived to 24 days of age at sites where eggs were laid.
Nestling survivorship	Proportion of chicks in a brood survived to at least 24 days of age.
Productivity	Number of chicks that survived to at least 24 days of age at hatching successful sites.
Fledging condition	Body mass divided by tarsus length for chicks at least 24 days old. Data are brood means for each gender.

Appendix B. Reproductive variables for American kestrels in southwestern Idaho, 1992-93.[a]

Variable[b]	*n*	%	Mean ± SE	Range
Median hatching date	78		151 ± 1.78	117-189
Egg laying	81	70		
Clutch size	78		4.9 ± 0.06	3-6
Egg abandonment	103	26		
Hatching success	78	94		
Hatchability	70		0.82 ± 0.03	0.0-1.0
Breeding success	108	67		
Nestling survivorship	62		0.96 ± 0.02	0.4-1.0
Productivity	71		4.2 ± 0.03	1-6
Fledging condition				
males	43		2.7 ± 0.05	1.9-3.8
females	45		2.8 ± 0.04	2.0-3.2

[a] Pooled data for 3 treatment combinations and 2 years.
[b] Variable definitions in Appendix A.

Site Fidelity in the American Kestrel in Southwestern Idaho

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ANNUAL SUMMARY

*Nest boxes in Southern Idaho were monitored to determine the frequency of American Kestrels (**Falco sparverius**) returning to previously used nesting sites. Kestrels monitored in this study area demonstrated a low rate of return to previously used nest boxes. Many boxes used by marked adults in 1992 were not re-occupied, and some were occupied by new adults. Only 1 adult (female) returned to breed in the same box where she bred in 1992. However, 1 male and 1 female returned to boxes they had used in 1991, and another female was recaptured near the box she used in 1992. Individuals of this population that did return to a nest site had previously fledged young at the same site.*

INTRODUCTION

The American kestrel is a widely distributed falcon that is abundant over much of the North American continent. Sexes are dimorphic and in some regions are known to winter in separate areas (Stotz and Goodrich 1989). Individual adult raptors exhibit various movement strategies during the nonbreeding season: (1) in some populations, both members of a pair remain on their territory; (2) in some breeding pairs, only 1 sex, typically the male, remain on the breeding site year round ; and (3) in other populations both sexes migrate out of the area (Newton 1979). During the early breeding season, kestrels may enhance their fitness by inhabiting a territory that they previously occupied (Gonzalez 1986). Reoccupying a familiar territory may benefit the male at nesting time because he has prior knowledge of prey concentration areas and suitable nest sites. This prior knowledge of the area may be more crucial for the male than the female because he is primarily responsible for nest site selection and obtaining prey for the pair (Balgooyen 1976). Fidelity to a breeding site or territory may also be related to migratory habits, age and previous success of a bird in a specific area, and quality of the territory. Alternately, advantages of changing breeding territory include the possibility of obtaining a better mate and an improved nesting and foraging habitat. Given presumed advantages, both male and female kestrels may receive benefits by returning to a traditional nesting territory. However, the advantage of finding the most suitable mate may override site fidelity, especially for the female who depends heavily on food provisioning by the male when nesting (Bowman and Bird 1987).

In southwestern Idaho it is not known if the populations of the American kestrel are resident or migratory. Groves and Steenhof (1987) reported that kestrels live in Idaho year-round, but that some may migrate south for the winter. This statement, however, is based on very limited data (K. Steenhof, Natl. Biol. Surv., pers. commun.). Resident populations of raptors may show

greater fidelity to breeding sites than migratory populations. The frequency with which marked kestrels return to established nest boxes and the factors that may affect the fidelity of kestrels to breeding areas in southern Idaho are uncertain. Comparing the return rates of male and female kestrels in a population will help determine how nesting success during previous years may affect fidelity to the breeding territory and whether 1 sex is more faithful than another. Here I report on a study of marked American kestrels and begin to answer the questions: (1) Is 1 sex more faithful to their breeding territory than the other? (2) Does nesting success during previous years affect fidelity to the breeding territory?

METHODS

The Bureau of Land Management (BLM), in cooperation with the Idaho Fish and Game and the Idaho Department of Transportation, erected nesting boxes designed for use by the American kestrel in the rural farmlands of Kuna, Idaho and along U.S. Interstate 84 between Simco Road and Caldwell, Idaho (Groves and Steenhof 1987). The boxes along U.S. Interstate 84, (hereafter referred to as the I84 Route), were placed on the back side of large highway signs and the boxes in the Kuna vicinity (hereafter referred to as the Kuna Route), were attached to trees within agricultural habitat (Steenhof 1992).

The Bureau of Land Management has been opportunistically banding adult kestrels since 1985. No previous systematic effort has been made to determine what proportions of these marked kestrels return to use nesting boxes in the study area in subsequent years.

Beginning in late February, I trapped and banded kestrels using a Bal-chatri trap (Berger and Mueller 1959) along the 2 study routes. As the breeding season progressed, all boxes that contained evidence of nesting activity were revisited to capture adult birds. In late April, the boxes were checked for incubating birds, and adults were captured inside the boxes. I captured incubating adults by plugging the entrance hole to the nest box. If an adult was present, I carefully removed it through a hinged door on the side of the box. All adults captured were checked for the presence of a band and weighed with a Pesola scale; we also measured wing chord. Boxes that did not show nesting activity were periodically checked until I was certain that no kestrels would use them for nesting in the 1992 season. Nests of European starlings (*Sturnus vulgaris*) were removed from any boxes in order to promote kestrel nesting. This process continued until 2 May 1993. Subsequent efforts to trap kestrels active in the study area, conducted by Steenhof, Bednarz and Carpenter using mist nets placed around a live great-horned owl (*Bubo virginianus*), are also considered in this paper.

RESULTS

Of 49 boxes available, kestrels were associated with 17; 10 boxes on the I-84 Route and 7 boxes on the Kuna Route. By 2 May 1993, 27 birds were captured. Eighteen kestrels were captured using the Bal-chatri trap, and 9 were captured in nest boxes. Individuals captured with 50 m of an occupied nest site using Bal-chatri traps or in a mist net adjacent to the box were considered to be part of the breeding pair using that nest box. By the end of the season, we had captured 25 adults at or near 15 boxes (Table 1).

Two of the captured individuals had been banded in the study area during 1992, both of these were females located along the Kuna Route. One of these females was recaptured near an unoccupied nesting box, Kuna-16, where she had produced young the previous year. At Kuna-110, another female was recaptured on 8 April at the nest, where she had been banded as an adult and had successfully raised young in 1992.

Additional trapping with mist nets during the brood rearing period resulted in the recapture of 2 additional birds. A female kestrel was captured at I-84-11. She was originally banded there in 1990 and successfully produced young there that year. This female had been recaptured in 1991 at the same nest site, but the nesting attempt failed. This box was used by a different female in 1992, but in 1993 the 1990-91 female returned and successfully fledged young. A male kestrel was also recaptured along the Kuna route at Kuna-110 on 26 May; he had fledged young from the same site in 1991, but it is not known whether he nested there in 1992 because the male was not captured in that year.

A previously banded female kestrel was captured inside an empty nest box along the I-84 route, I-84-8. She was originally captured in the Goshutes

Table 1. Kestrels captured and marked at or near nest boxes in 1993.

Nest Box No.	Status	Number of Fledged Young
I-84 1	both male and female captured	1
I-84 2	both male and female captured	4
I-84 3	both male and female captured	1
I-84 6	both male and female captured	6
I-84 8	banded Nevada female captured	no eggs laid
I-84 11	male captured, female recaptured	3
I-84 16	female captured	4
I-84 30	female captured	failed
I-84 31	both male and female captured	5
Kuna 13	female captured	failed
Kuna 16	female recaptured	no eggs laid
Kuna 103	female captured	5
Kuna 107	male recaptured[a], female captured	4
Kuna 109	male and female captured	2
Kuna 110	male and female recaptured	4
Kuna 112	female captured	5

[a] Recaptured in the same year.

Mountains of Nevada on 5 September 1989 as a hatch-year bird. A nesting attempt at that box was never initiated, and starlings were later found in the same box on 3 June.

In 1992, 16 adult kestrels (2 males and 14 females) associated with nest boxes were banded. Neither of the 1992 banded males returned to the same box in 1993 (Table 2). One of the boxes occupied by a marked male in 1992 (I-84-3) was occupied by a new male; another (I-84-18) was not occupied in 1993. Six of the 14 boxes occupied by marked females in 1992 were not reoccupied in 1993 (Table 2), and new females occupied 5 others. Only 1 female bred in the same box where she had bred in 1992 (Kuna-110). Another female was recaptured near her 1992 box (Kuna-16) where no nesting attempt occurred in 1993, and we were unable to capture the female at another box (Kuna-14).

DISCUSSION

Kestrels inhabit desert to alpine terrain and are known to commonly occur in suburban and urban environments. Although kestrel breeding is highly dependent upon available nesting cavities, they have demonstrated a willingness to breed under a variety of constraints in the wild

Table 2. Status of boxes where 16 banded adults occurred in 1992.

1993 Status	1992 Banded Male	1992 Banded Female
Reoccupied by the same adult.	0	2[a]
Not Re-occupied in 1993.	1	6
Occupied by a new adult.	1	5[b]
Occupied, but identity of adults unknown.	0	1

[a] Includes Kuna-16 where the 1992 female was trapped within 20 m of the box, but the box was not used in 1993.
[b] Includes I-84-8 where a new female was captured in the box, but no eggs were laid.

and captivity (Palmer 1988). The migratory patterns of the kestrel vary greatly depending upon latitude. The populations in many temperate areas tend to be resident, whereas the more northern birds will migrate south until they find suitable winter habitat (Gonzalez 1986).

The American kestrel is a small falcon with relatively high adult mortality (Newton 1979). Surplus nonbreeding kestrels, who are available to replace a lost mate (Bowman and Bird 1987), could serve to counter the relatively high mortality rate and limit the frequency of long-term pair bonding. These characteristics foster adaptability to a variety of situations and may discourage expenditure of energy in long migrations to return to a specific nesting site. Unlike other raptors (Newton 1979), kestrels may use the first available suitable nesting area they encounter, rather than returning to previously used sites. If this is the case, low rates of nest fidelity might occur in the American kestrel in southwestern Idaho. The low recapture rates resulting from this study support this hypothesis.

Factors that describe an ideal nesting habitat include availability of food, perches suitable for hunting, and available nesting sites. If these conditions are available, raptors tend to return to breed in a specific area (Newton 1979). Gonzalez (1986) found that individual kestrels in Utah were more apt to return to a territory if they successfully fledged young there the previous year. This pattern may be especially common in resident populations. Between 1986 and 1992, 62 adult female kestrels and 22 adult male kestrels have been marked in the Kuna and I-84 boxes by the BLM (Steenhof 1992), and an additional 20 were banded this year. Only 4 kestrels were recaptured during the 1993 field season. These low return rates suggest that kestrels in this study area are not frequently returning to the same nesting territory in successive years. The appearance of the female kestrel from Nevada also supports the idea that kestrels in southern Idaho are relatively migratory in nature and tend not to select the same breeding territory year after year. If there is a resident population in southwestern Idaho, individuals may exhibit faithfulness to boxes where they were previously successful. The kestrels that did return to the breeding area were all previously successful in their breeding attempts at the same locations. This suggests that a small portion of the breeding population within the study area may be faithful to their nesting territory and that this behavior may be related to the previous year's success.

Kestrels are seasonally monogamous but it is unlikely that they have lifelong pair bonds (Johnsgard 1990). The sexes winter in different habitats, with males returning to the breeding territory first. The male defends not only the nest but the entire breeding territory, whereas the female engages in little defensive activity (Palmer 1988). Female kestrels have been known to be more mobile than males and winter further south (Layne 1982, Gonzalez 1986). This greater distance moved by females may reduce the probability that an individual will successfully return to a specific area. Therefore the female, in finding a breeding area, may be more opportunistic than the male and select the first quality mate she encounters rather than returning to a previously used site. Gonzalez (1986) found that male kestrels showed less of a tendency to move away from a breeding territory, and if they moved, the distance was not great. The male kestrel is responsible for establishing the nesting site and procuring most of the prey for the pair. This, coupled with evidence that male kestrels are the primary defender of the breeding territory, suggests that site fidelity might be more beneficial to males than females. Results of this study, however, do not suggest that the male kestrels returned more frequently. Previous banding, however, was opportunistic and more females were captured while incubating than males. Future emphasis on capturing both kestrels of a breeding pair may help to further address this question.

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I would like to thank Karen Steenhof and Jim Bednarz for their guidance and support of this study. Additionally, their work with George Carpenter using the great-horned owl and mist net was of great significance to this study. Jim Tucker and Jack Small were also a great help during the trapping season. Receipt of a research grant provided by Societas Biofilis of Boise State University and support from the Bureau of Land Management, Raptor Research Department was also vital to successful completion of this project.

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Breeding Biology of Northern Saw-whet Owls in Southwestern Idaho

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ANNUAL SUMMARY

*Northern saw-whet owls (**Aegolius acadicus**) have occupied nest boxes in the Snake River Birds of Prey Area (SRBOPA) since 1986, and at Deer Flat National Wildlife Refuge (DFNWR) since 1989. This report summarizes the reproduction and body mass data that have been collected for saw-whet owls using these boxes since 1986. It also reports on the occupancy of these boxes by saw-whet owls in 1993.*

OBJECTIVES

1. To determine breeding biology of northern saw-whet owls.
2. To collect habitat characteristics at occupied and randomly selected unoccupied nest boxes.
3. To collect diet information to determine niche-overlap between saw-whet and western screech-owls (*Otus kennicotti*).

METHODS

Nest boxes were checked biweekly starting 15 February to determine occupancy of boxes in the 2 areas. For description of study areas see Rains (1992). Occupied sites were monitored to determine laying dates, clutch size, hatching success, brood size, and fledging success.

Northern saw-whet owl reproductive and body mass data have been collected since 1986. A breeding attempt was considered successful if ≥1 young reached 80% age of fledging. Laying dates were calculated either independently or by back-dating from hatch dates. Adult owls were sexed based on the presence of a brood patch in the females. Owls body mass was obtained using a pesola scale. Wing chord length was measured using a ruler.

Habitat measurements were collected at the 17 nest sites occupied by northern saw-whet owls in SRBOPA since 1986; the remaining 3 nest sites have been destroyed. Measurements were also collected at 47 randomly selected non-occupied nest sites. Measurements obtained were canopy coverage, ground cover, nest box and nest tree measurements. All nest box locations were identified using a Global Positioning Satellite (GPS) unit.

Nest box material was collected from the 2 occupied saw-whet owl nest boxes, 1 from SRBOPA and 1 from DFNWR. This material will be examined (Rains 1992) to determine diet.

RESULTS AND DISCUSSION

Nesting northern saw-whet owls have been monitored in the SRBOPA and DFNWR since 1986. The overall average laying date was 13 March, and the overall average hatching date was 9 April. Clutch size ranged from 4 to 8 eggs with a mean of 5.8 (Fig 1). At some nests 1 or more eggs hatched before the clutch was observed; these clutches were included in the average clutch size. A total of 37 nesting attempts (29 SRBOPA, and 8 DFNWR) fledged 55 young for an overall mean annual productivity of 1.49 young/nesting attempt since 1986 (Figs. 2 and 3).

Since 1986, 148 northern saw-whet owls have been banded in southwestern Idaho. Of these owls, 108 were nestlings (sex undetermined), 18 adult males, and 22 adult females. No saw-whet owls were captured or banded in 1993. Wing chord and body mass measurements were used only for adults whose sex was determined (see methods). Mean body mass was 125 gm for females and 77 gm for males (Table 1). Some owls were weighed more than once during the breeding season. These mass measurements were analyzed to determine mass loss. Females lost an average of 0.59 gm/day; males lost 0.05 gm/day (Table 2). Wing chord measurements were obtained from adult owls. Female wing chord length was 144.1 mm, and male length was 135.5 mm (Table 3).

The 2 sites (Bruneau Marsh West #2, and Lake Lowell #12) occupied by saw-whet owls in 1993 were not accessible at the time of fledging, and

Table 1. Northern saw-whet owl body mass measurements (grams). Adult owls from southwestern Idaho were captured and weighted with a pesola scale from 1987 through 1993. Measurements were included only if sex of adult was known (presence of brood patch).

	Mean	SD	Range	*n*
Female	125	10.3	103-145	23
Male	77	3.3	70-81	17

Table 2. Average weight loss/day of female and male northern saw-whet owls during the breeding season.

	Average No. of days between weighings	Weight loss/day (gm)	Range (gm)	*n*
Female	19.6	0.59	2 - 30	5
Male	33.0	0.05	3 - 4	2

Table 3. Wing chord measurements of adult northern saw-whet owls from southwestern Idaho. Measurements were included only if sex of adult was known (presence of brood patch).

	Mean (mm)	SD	Range (mm)	*n*
Female	144.1	6.3	135-152	7
Male	135.5	0.7	135-136	2

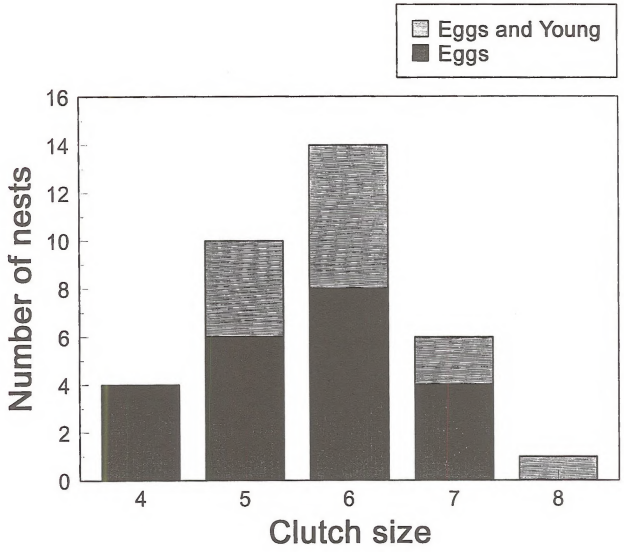

Fig. 1. Clutch size of northern saw-whet owls in southwestern Idaho, 1986-92. In some cases 1 or more eggs hatched before the clutch was observed; these clutches were counted as eggs and young.

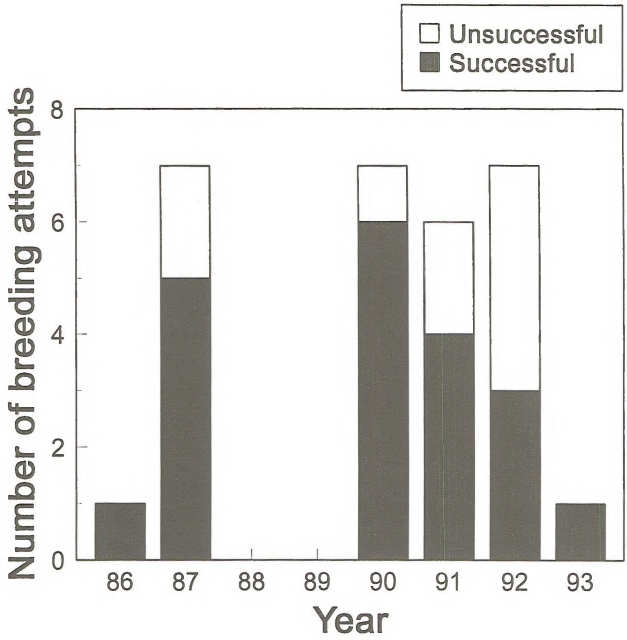

Fig. 2. Nesting success of northern saw-whet owls in Snake River Birds of Prey Area, southwestern Idaho, 1986-93. Breeding attempts were considered successful if 1 young reached 80% age of fledging (22 days).

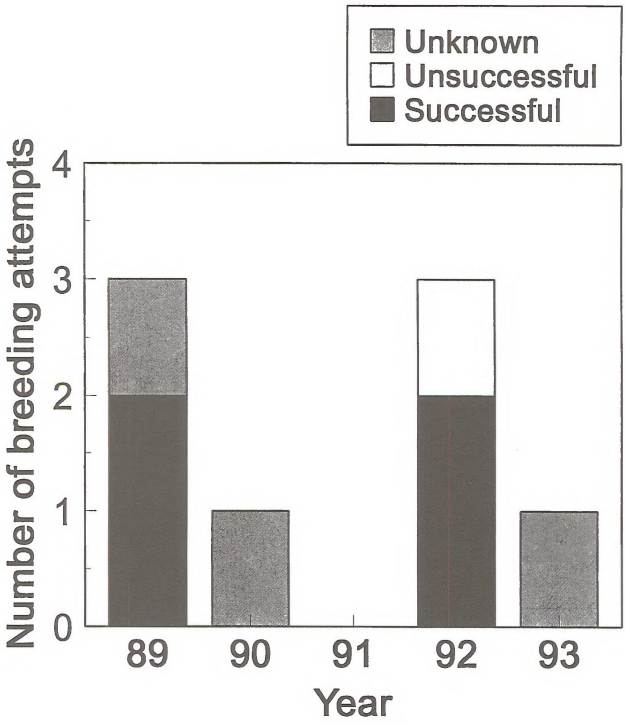

Fig. 3. Nesting success of northern saw-whet owls in Deer Flat National Wildlife Refuge, southwestern Idaho, 1989-93. Breeding attempts were considered successful if 1 young reached 80% age of fledging (22 days).

therefore the fate of the nesting attempt was unknown. The young were 10-17 days old at both sites when last seen, and the condition of the nest box at the last check would indicate that the young probably fledged.

PLANS FOR NEXT YEAR

Northern saw-whet owls pellets collected at SRBOPA and DFNWR since 1986 will be analyzed to obtain diet information. Western screech-owl pellets collected at SRBOPA will also be analyzed, and a comparison of diet between the 2 species will be used to determine niche overlap. Habitat measurements not obtained in 1993 will be obtained in 1994, and all habitat measurements will be analyzed. Nest boxes will be checked in SRBOPA, and reproductive and diet data will be collected at any saw-whet owl nest sites.

ACKNOWLEDGMENTS

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Nest Box Use in the Snake River Birds of Prey Conservation Area

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ANNUAL SUMMARY

*Roosting or breeding raptors used boxes at 30 of 46 available sites in 1993. Western screech owls (**Otus kennicottii**) used 29 of 46 sites and bred at 13. The temporal spread of screech owl breeding was much wider in 1993 than in past years. This may have been due to a lack of small mammals in the study area.*

OBJECTIVES

To determine patterns of nest box use, fidelity to site and mate, reproductive success, food habits, annual body mass and the relationship of wing cord to sex and age in western screech owls.

METHODS

Ninety-three boxes were available to owls at 46 sites during 1993. Access to 2 sites was blocked by a property owner who owned the right-of-way. All other nest boxes were checked monthly from October through May. Boxes containing breeding screech owls were visited in May and June to band nestling owls. Adult size screech owls captured in the boxes were weighed with a 300-g Pesola spring scale and the flattened wing cord was measured to the nearest millimeter. The owls were sexed by the presence or absence of a brood patch during the breeding season. The adult size owls were age classed by the color of the underwing. After fledging, prey remains were collected from nest boxes. All boxes are cleaned and repaired as needed throughout the year.

RESULTS

Twenty-nine of 46 sites were used by roosting or breeding screech owls. Thirteen sites were used by breeding screech owls. Eleven adult size and 34 young screech owls were banded. Fifty-three body mass and 51 wing cord measurements were obtained from adult size owls. Fifteen female body mass measurements taken outside the breeding period ranged from 201 to 246 g. Nine male body mass measurements ranged from 170 to 222 g. The body mass of unknown sex owls ranged from 156 to 243 g. The wing cord measurements ranged from 183 to 193 mm for females, 176 to 188 mm for males and from 172 to 192 mm for owls of unknown sex.

Northern saw-whet owls (*Aegolius acadicus*) nested at one site. These owls had 5 young approximately 15 days of age on 3 May. Flooding of the Bruneau marsh kept investigators out of the

area until 25 May. By this time the young had apparently fledged and dispersed from the area. None of the adult or young saw-whets were banded. Prey remains were collected from the nest box.

American kestrels (*Falco sparverius*) nested in 7 boxes at 5 sites. No information on kestrel was gathered but prey remains were collected from their nest sites.

Boxes were placed at 3 new sites in 1993.

DISCUSSION

My statement in the 1992 report that boxes placed for saw-whet owls at five sites had entry holes to small for screech owls to utilize was proven to be untrue. A pair of screech owls nested in one of these boxes with a 6.35 cm diameter entrance hole.

The 1993 breeding season would have ranged from March through July if all young owls had lived to fledging. In past years all young have been banded by late May. This year young were banded from 12 May through 17 June. Had they lived the young at Jacks Creek would have been banding age on 1 July. These young were approximately 10 days of age on 17 June. My assumption is that the wide temporal range in breeding was due to the lack of small mammals in some territories. I believe that the adults at the later breeding sites waited until migrant passerine birds came into their territories in large enough numbers to give the owls sufficient prey to gain the energy to breed. The upper weights of female screech owls in 1993 is about 40 g below the weight of the heaviest owls in past years. This weight difference could be the result of lack of prey. Of course it may just reflect timing of visits that failed to find female owls that had just eaten. On 30 December 1993 I found what appears to be cannibalism among western screech-owls. The beak and head feathers of a hatch year owl were found in 1 box at the Delta South site, and the wings, 1 leg, and body feathers were found in the second box at this site. This possible lack of mammalian prey might account for there only being 1 pair of breeding saw-whet owls in 1993.

PLANS FOR NEXT YEAR

The objectives of this study will remain the same. A cooperative study of western screech owl physiology, habitat, use and dispersal of young will be initiated with personnel from Boise State Universities graduate program for raptor studies.

ACKNOWLEDGMENTS

I thank Charley Rains, Rick Olendorff, Jeff Marks, Matt McCoy, and Alison Perkins for their help monitoring nest boxes during 1993. I thank Dick Orcutt for allowing access to sites in the C. J. Strike Wildlife Management Area. I thank Karen Steenhof for her editorial assistance in preparing the annual reports.

Feeding Ecology of the Barn Owl in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

Surveys of traditional barn owl nest/roost sites revealed evidence of roosting at 4 sites, but nesting at only 2 sites (1 a concentration of several pairs). Diet data revealed pronounced changes in several major prey, most notable of which were the 14% increase in voles and 13% decrease in pocket gophers, and 6% increase in house mice and 6% decrease in deer mice.

OBJECTIVE

To determine food-niche parameters and food-niche variation among collection sites and among years for barn owls (*Tyto alba*) nesting in the Snake River Birds of Prey Area (SRBOPA).

METHODS

Owl diet data originated from regurgitated pellets that I collected at cliff sites occupied by barn owls. Most sites were occupied barn owl nests. All collections were made on 1-2 May and 12 June. Prey in the pellets were identified and quantified by standard methods (Marti 1987). See Marti (1988) for treatment of data from earlier years.

RESULTS AND DISCUSSION

Pellet samples were collected at 4 sites in 1993. Collection locations and sample sizes are given in Table 1. The 1993 dietary sample is summarized in Table 2. Four prey species exhibited major changes in dietary proportions compared to 1992.

Voles (*Microtus montanus*) increased in barn owl diets by 14% from the preceeding year, and pocket gophers (*Thomomys townsendii*) decreased by almost the same proportion (13%). The house mouse (*Mus musculus*) and deer mice (*Peromyscus* spp.) also showed complementary changes in barn owl diets from 1992 to 1993: house mice increased and deer mice decreased by 6%. See Marti (1991) for diet trends beginning in 1978.

Evidence of owl use was found at 4 sites in 1993, but nesting was documented at only 2 (Lower Lower Black Butte and Upper Lower Black Butte). One site, Upper Lower Black Butte, probably contained a concentration of 3 pairs of nesting barn owls. See Marti (1990, 1991, 1992) for comparisons of the number of occupied sites and size of diet samples in other years.

PLANS FOR 1994

Three trips to the SRBOPA are planned for the spring/summer of 1994. The objectives for 1994 are to continue collecting food habits data for the analysis of long-term predation trends by barn owls and to monitor trends in breeding numbers of barn owls at the traditional study sites.

Table 1. Collection sites for barn owl diet data and number of prey in collection samples from the SRBOPA, 1993.

Collection Site	Number of Prey in Samples	
	May	June
Jensen Cliff	42	
Lower Lower Black Butte	80	80
Upper Lower Black Butte	765	393
Garbage Draw	293	

Table 2. Total prey identified for the barn owl in the SRBOPA, 1993.

Prey species	Number	Percent number
MAMMALS		
Sorex vagrans	2	0.1
Sylvilagus nuttallii (neo.)	2	0.1
Mus musculus	195	11.8
Peromyscus spp.	111	6.7
Onychomys leucogaster	1	0.1
Reithrodontomys megalotis	45	2.7
Neotoma lepida	1	0.1
Microtus montanus	1031	62.4
Perognathus parvus	14	0.8
Dipodomys ordii	124	7.5
Thomomys townsendii (juvenile)	91	5.5
BIRDS		
Sturnus vulgaris	5	0.3
unidentified icterid	6	0.4
unidentified small bird	25	1.5
Totals	1653	100

ACKNOWLEDGMENTS

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Wintering and Nesting Site Use by Long-eared Owls in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

I checked 7 winter roost sites and found a total of 21-23 long-eared owls (Asio otus) at 6 of the sites. Between 13 December and 20 February I captured a total of 14 owls at 4 of these sites; 5 were recaptures. During the breeding season, I checked 14 nesting groves and found 5 nests at 4 sites. I banded 11 juveniles and caught 2 adult males and 2 adult females; 1 female and 1 male were recaptures.

OBJECTIVES

1. To gather long term demographic data on nesting and wintering long-eared owls in the Snake River Birds of Prey Area.

METHODS

In the winter, I searched for long-eared owls in roosting groves where I have trapped owls in previous winters. I trapped owls during the day by setting 4-cm-mesh mist nets in flight paths within the roosting groves, usually in flight paths into the roost site. I either flushed owls back and forth to cause them to fly into the nets, or waited for them to return on their own to their favored roost site. I weighed owls with a 300- or 1000-g pesola scale, and banded all unbanded owls. I used coloration of the remiges to determine age: a pink wash on the underside of the wings indicates freshly molted feathers, and thus an adult bird. This characteristic is best early in the winter, and fades later in the season. A more definitive characteristic is 2 tones on the top surface of the remiges, which results from an adult owl only partially molting its remiges during the summer. The old feathers will be paler than the new feathers. If 2 tones are present, the owl is definitely an adult bird; however, I have recaught some owls which I knew were adults that did not have 2-toned remiges. Thus, an owl with even-toned remiges may be either an adult or a first-year bird.

In the breeding season, I captured and banded adult owls during the branching or fledgling stages, using a mist net baited with a plastic great horned owl (*Bubo virginanus*) decoy at dusk or night. I set the decoy on a pole near the middle of a single net, with the decoy below the top of the net. I set the net outside the nest grove, in a position so that the great horned owl decoy would be silhouetted against the sky. I trapped a lone adult owl at Nahas marsh by setting nets perpendicularly out from the riparian grove and checking them through the night. (With this net set we also caught a spotted bat [*Euderma maculatum*] and a western screech-owl [*Otus kennicottii*]).

I weighed all adult owls, and determined sex by the presence or absence of a brood patch, and by relative weights of a pair (the female is heavier than the male during breeding season, see

below). I banded young owls during the last week of the nestling period or the first 2 weeks of branching.

For the last 2 seasons, since I started using 2 new nets, I have had problems with owls escaping from nets, in both the winter and breeding seasons, but particularly in the breeding season. In previous years, if owls responded to the great horned owl decoy by screaming and diving at it, I was certain to capture them. With the new nets, I had as many as 4-6 adults attacking at once without catching any. I have finally figured out what the problem was. In fall 1991 I bought 2 new mist nets; when these nets arrived I discovered that they only had 2 tiers instead of 4 tiers like my old nets. I used them as they were, and they seemed to work in the winter when the owls often fly straight into the net as they zoom into their winter roost (although I did have some owls escape out of the bags). In breeding season, however, the owls dive at a slant to the net as they attack the decoy from above. In this situation, the large bags on the new nets were too large and soft, the owls would not get any body part through the mesh, and they would flop out of the bags. Meanwhile, I tried using my old nets also, but they were getting rotten and the birds broke through them. I have apparently solved the problem with the new nets by threading nylon line horizontally through each bag of the new nets to split it in half and create 4 tiers with smaller bags.

RESULTS AND DISCUSSION

Wintering

On 5 days from 13 December 1992 through 20 February 1993 I checked 7 wintering sites, and found 21-23 long-eared owls at 6 of the sites (Table 1). This number is slightly lower than last year. I captured 14 of these owls, at 4 of the 6 sites where I trapped. Of these, 9 were new birds and 5 were recaptures (Table 2). One of the recaptures was a male ("Tom") that I have caught 5 times at Tom Draw, in 3 winter seasons and 2 breeding seasons. We originally banded him in January 1988 as an AHY (after hatch year) bird. Thus Tom was in his seventh year, assuming he hatched in 1987.

On 13 December 1992, we discovered a northern saw-whet owl (*Aegolius acadicus*) roosting in thick willows at the mouth of Fossil Creek. On 20 February 1993 during a search of Nahas marsh, I encountered 3 northern saw-whet owls roosting low (<2 m) in dense willows, all within a few 100 m of each other. These were the first saw-whet owls I have found winter-roosting in long-eared owl groves.

Breeding

During the breeding season, I checked 14 sites and found 5 nests at 4 sites (Table 3). Bruneau Arm and Bruneau Flats Road are probably no longer suitable nest sites because the willows are mostly dead from lack of irrigation water. Nicholson Pond groves were burned by a rancher in 1990 and have not yet regrown sufficiently to provide cover or support for magpie and crow nests. Sinker Creek Butte and Strike Ditch were both new nesting sites for me, which other biologists told me about. I had the searched Sinker Creek Butte grove in 1988 without success, and never revisited it.

At least 11 young (which I banded) fledged from 3 of the 5 nests; I did not recheck the other 2. I

Table 1. Sites searched for roosting long-eared owls during the winter of 1992-93 in the Snake River Birds of Prey Area, Idaho.

Site	Date	# Seen	# Banded	# Recaptures
No Name Creek	13 Dec 92	2	0	0
Fossil Creek	13 Dec 92	0	–	–
Loveridge Bridge	19 Dec 92	1-2	0	0
Crane Falls Sturgeon	19 Dec 92	1	1	0
Nahas Marsh	2 Jan 93	12-13	6	2
Castle Ck Mouth N	3 Jan 93	2	1	1
Tom Draw	20 Feb 93	3	1	2
Nahas Marsh	20 Feb 93	4-5	0	0

Table 2. Recaptured long-eared owls from January 1988-June 1993 in the SRBOPA. Captures from December 1992 to May 1993 are in italic type.

Location Banded	Band Number	Sex	Dates Captured (Wt. in Grams)
Castle Ck Mouth N	816-44041	?	Apr 87 (juv); Jan 91 (281)
Tom Draw	896-36733	M	Jan 88 (271); May 89 (231); Dec 90 (245); May 91 (228) *Feb 93 (255)*
Tom Draw	896-36734	?	Jan 88 (272); Jan 89 (248)
Tom Draw	896-36735	M	Jan 88 (276); Jan 89 (252); May 90 (240)
Tom Draw	816-74512	?	May 88 (268); Jan 89 (252)
Tom Draw	816-74592	?	Dec 89 (248); Dec 90 (268)
Tom Draw	816-74599	?	Dec 89 (249); Dec 90 (282)
Tom Draw	816-74909	?	Dec 90 (249); Feb 91 (250)
Tom Draw	816-74595	?	Dec 89 (241); Jan 92 (265) and *Jan 93 (277)* - at Nahas Marsh
Castle Ck Mouth N	816-74922	F	Jan 91 (>288); May 92 (292)
Fossil Creek	816-74927	?	Feb 91 (277); Jan 92 (250) - at Tom Draw
Fossil Creek	816-74929	M	Feb 91 (272); May 91 (219) *and Jan 93 (266)* - at Castle Mouth N
Fossil Creek	816-74931	?	Feb 91 (269); Feb 92 (250)
Castle Ck Mouth N	816-74979	?	Jan 92 (223); Feb 92 (—) - at No Name Cr mouth
No Name Creek	816-74998	F	Feb 92 (345); May 92 (323)
Nahas Marsh	*816-74984*	*F*	*Jan 92 (323); Jan 93 (316); Feb 93 (323) - at Tom Draw*
Strike Dam Road	*816-74977*	*M*	*Jun 91 (222); May 93 (245)*
Nahas Marsh	*816-74793*	*F*	*Jan 93 (295); May 93 (314)*

Table 3. Nests of long-eared owls in the Snake River Birds of Prey area in 1993. Other sites searched with no nests found are: Loveridge Bridge, Bruneau Arm, Bruneau Flats, Crane Falls Sturgeon, Emigrant Trail South, Fossil Creek Mouth, No Name Creek mouth, Nicholson Pond NW and NE, Castle Ck. Mouth N, and Nahas Marsh.

Site	Adults Trapped	# Young	# Juv Banded	Fate
Bruneau Flats Road	—	?	—	?
Strike Dam Road	M	3 eggs	—	?
Strike Ditch	0	@2	2	?[b]
Sinker Creek Butte North	0[a]	5	5	successful
Sinker Creek Butte South	2[a]	4	4	successful

[a] These sites were only a few 100 m apart, and I can not be sure which nest the adults were from. However, I assigned them to the South nest because it was about a week younger and the adults should have been more defensive at the time I caught them.

[b] Young were 3 weeks old when last seen.

trapped for adults at Strike Ditch and Sinker Creek Butte without success before I altered my nets (discussed in Methods above). On a second try with altered nets at Sinker Creek Butte, I caught 2 of the 4 adults. I also trapped at Strike Dam Road, and caught the male, a banded bird I had first caught breeding in 1991 at the same site. I trapped 1 male at Nahas Marsh but did not find any young or nest there; we may have been late and the young may have already left.

Summary 1988-1993

Since January 1988 I have banded 229 owls (26 breeding adults, 84 wintering adults, and 119 juveniles) and recaptured 18 owls a total of 24 times (Table 4). At winter roosts, 60% of the captured owls were in their first year, and 40% were older birds (N = 100).

Table 4 summarizes the categories of site fidelity exhibited by the 18 recaptured owls. These data show that some long-eared owls have a degree of fidelity to an area (the Snake River in the BOPA) for wintering and breeding, and even to a particular site (grove of trees). Jeff Marks found a greater percentage of returning juveniles in the BOPA, males that returned as yearlings to breed near their natal territories (Marks, J.S. Yearling male Long-eared Owls breed near natal nest. J. Field Ornithol. 56:181-182). So far I have not trapped any returning breeding owls that I banded as local juveniles.

The numbers of long-eared owls that I have counted at the main roost sites since the winter of 1987-88 have varied widely (Fig. 1). Although the data are incomplete because I do not have counts at every site every year, the graph shows a basic pattern of increasing numbers from the winter of 1987-88 to 1990-91, and then decreasing numbers to the winter of 1992-93. I think these data reflect a true pattern despite being incomplete because the numbers of wintering long-eared owls generally track the numbers of kangaroo rats (*Dipodomys* spp.) per kilometer counted on spotlight transects in the BOPA during the previous summers (also shown on the graph.)

It also appears that the owls tend to concentrate in 1 main roost in the area, with other smaller roosts nearby. For the first 4 years, Tom Draw appeared to be the main roost; during the last 2 winters, Nahas Marsh appears to have become the main roost. I did not check Nahas Marsh during the first 4 years, and so it might have had significant numbers of owls then, similar to Tom Draw. However, these sites are very near each other. Owls have moved as a group to different roosts about 0.5 km apart within Tom Draw; thus, I think it likely that the owls could also move across the river between Nahas Marsh and Tom Draw, the 2 sites functioning as essentially 1 roost area. It is also entirely possible that there are other important roosts that I have missed, particularly on private land.

Weights

It appears that males lose weight and females gain weight from winter to summer (Fig. 2). My data show no overlap in the ranges of weights of

Table 4. Summary of types of site fidelity exhibited by recaptured long-eared owls trapped in the Snake River Birds of Prey Area, Idaho, from 1987-1993. One owl may fit into >1 category. N = 18 owls recaptured 24 times.

Capture Category	Owls # (%)	Percent of Captures
Winter		
more than 1 winter, same site	9 (50)	11
more than 1 winter, different sites	4 (22)	5
same winter, different sites	2 (11)	2
Breeding and Wintering		
same site	3 ♂, 3 ♀ (33)	5
different sites	0 (0)	0
Breeding		
same site	2 (11)	8
different sites	0 (0)	0
Return to Natal Area		
winter	1 (5)	1
breeding	0	0

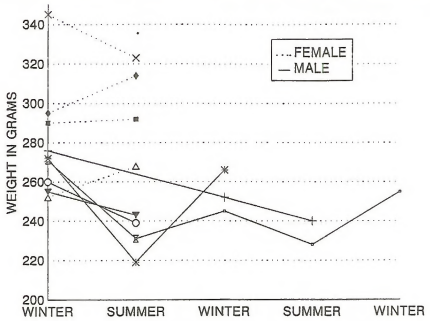

Fig. 1. Numbers of long-eared owls (bars) counted at winter roosts from the winter of 1987-88 to 1992-93, and numbers of kangaroo rats per kilometer seen during spotlight transects conducted by the BLM during the previous summers, in the Snake River Birds of Prey Area, Idaho. TD = Tom Draw, CMN = Castle Ck Mouth N, CFS = Crane Falls Sturgeon, FNN = Fossil and No Name Creek mouths, NM = Nahas Marsh.

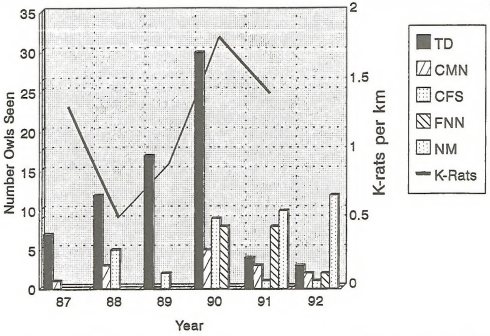

Fig. 2. Weights of adult long-eared owls recaptured during winter and breeding seasons in the Snake River Birds of Prey Area, Idaho. Some data from J.S. Marks, Univ. of Montana, pers. commun.

Table 5. Average, standard deviation (SD), median, and range of weights (g) of long-eared owls captured in the Snake River Birds of Prey Area, Idaho, 1988-1993.

	Winter N = 101	Breeding Males N = 15	Breeding Females N = 19
Average	271	232	288
SD	24	11	19
Median	265	234	284
Range	222-345	204-249	252-323

male and female long-eared owls during the breeding season (Table 5). Thus, during the breeding season, weighing breeding long-eared owls is a good way to determine sex, with females weighing >250 g and males weighing <250 g.

In the winter, it is more difficult to determine sex, because the weights of known-sex owls overlap. The heaviest known-sex winter male that I have weighed was 276 g; the lightest known-sex female that I have weighed was 252 g. Thus a winter owl >280 g is probably a female; I think any owl >300 g is certainly a female. Winter owls <250 g are probably males. However, 50% of winter owls weigh between 250 and 280 g. Thus, during winter, it is not possible to determine even the probable sex of at least half of long-eared owls by weight.

PLANS FOR NEXT YEAR

I plan to continue monitoring, trapping, and banding long-eared owls at as many sites as I can each winter and nesting season, if my Salmon BLM workload and the logistics of traveling from Salmon allow. I will at least trap in January 1994, on approved loan from the Lemhi Resource Area. Priority sites will be Tom Draw, Nahas Marsh, Fossil Creek Mouth, No Name Mouth, Castle Creek Mouth N, and Crane Falls Sturgeon.

ACKNOWLEDGMENTS

John Doremus has been my mainstay since 1988, because of his willingness to help and his keen field skills and knowledge. I thank the many other people who helped tote poles and trap owls this year: Roger, Conrad, and Lauresta Ruth; Peter and Kelsey Harrity; Jeff Marks and Alison; Bruce Zoellick; Jane Crosby; Julie Hall; Dave McCoy; Jim and Vicki Clark; and Donna Kreiensieck. The Boise Field Office of the U.S. Fish and Wildlife Service donated the much-needed use of a jet boat.

Short-eared Owl Mortality Between Mid-nestling Age and Dispersal

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ANNUAL SUMMARY

*I examined mortality in short-eared owls (**Asio flammeus**) between the mid-nestling period and dispersal from the natal area. Nesting success was confirmed at only 2 nesting areas. One pair failed during incubation. A second pair was successful and fledged 1 young. This bird was instrumented as a nestling with a tarsal-mounted radio transmitter and was monitored until it dispersed from the nesting area. A nest mate of this bird died at 15 days of age of unknown causes.*

OBJECTIVES

1. To document the degree of short-eared owl mortality that occurs between the mid-nestling period (12 days of age) and dispersal (approximately 60 days of age).

2. To identify the causes of short-eared owl mortality during the nestling and fledging periods.

3. To determine if a count of short-eared owl nestlings at or near 12 days of age is an accurate measure of reproductive success.

4. To determine if prey deliveries or food begging calls of nestling and fledgling short-eared owls can be used to locate young on the ground, as a means of determining reproductive success.

INTRODUCTION

In the Snake River Birds of Prey Area (SRBOPA), raptor nesting attempts are considered successful if 1 or more young reach 80% of the average age at which most young fledge (Kochert et al. 1991). This corresponds to 20 days for short-eared owls (Clark 1975). However, short-eared owl nestlings disperse from the nest on foot as early as 12 days of age, well before fledging age (about 25 days) (Clark 1975). By the time nestlings are 20 days old, they are well hidden in surrounding vegetation and are extremely difficult to count. This behavior has hindered efforts to measure reproductive success of short-eared owls in the SRBOPA (Lehman et al. 1992). I hoped to address this problem by radio-tracking up to 40 short-eared owl nestlings between their departure from the nest and dispersal from the natal area to assess the proportion of nestlings that die before dispersing. If survival is high before dispersal, a brood count in the mid-nestling period might accurately reflect fledging success. If survival is low, reproductive success will have to be determined at 20 days of age, after young have left the nest. This would require that young be located in surrounding vegetation. Thus, I also hoped to determine if food begging calls of nestling and fledgling short-eared owls could be used to locate young owls after they have left the nest.

METHODS

Locating Nests

Nests were located in conjunction with Study 3's benchland survey (Lehman et al., this volume). I conducted follow-up surveys in areas where short-eared owls were observed during quadrat surveys, historical nest checks, or incidentally. Surveys were done at dawn and dusk. Dawn watches typically began at first light, approximately 1 hr before sunrise, and continued until 1 hr after sunrise. Dusk watches began approximately 1 hr prior to sunset and continued after sunset until low light prevented further observations.

During daylight hours, I searched suspected nesting areas to flush adult short-eared owls. Searches were conducted within square plots centered on the location of the most recent short-eared owl sighting. Search patterns consisted of parallel line transects spaced at 5- to 20-m intervals, depending on vegetation density. I walked wider intervals in areas with low vegetation density. The effective search area extended 400 m or more in all directions from the center of the plot. At 2 nesting areas, a 35-m long rope was dragged across the top of vegetation in an attempt to flush incubating adults. During these searches, 8 volunteers spaced along the length of the rope walked a search pattern similar to that described above for square plots.

SAMPLING PROTOCOL

I planned to instrument all nestlings in each nest when the oldest was approximately 12 days old. However, I found only 1 nest with young, and was able to instrument only 1 nestling. That nestling was weighed, banded with a USFWS band on 1 leg, and equipped with a 6.5-g radio transmitter on the other leg. The transmitter contained a mortality circuit that doubled the pulse rate to 60 pulses per min if the transmitter remained stationary for more than 8 hrs. It was manufactured by Advanced Telemetry Systems, Isanti, Minnesota, and had a minimum guaranteed lifetime of 60 days. Nestling age at the time the transmitter was attached was based on Karalus and Eckert (1987) and Johnsgard (1988).

RADIO TRACKING

Survival of the radio-equipped nestling was monitored at 1- to 4-day intervals. Typically, this involved detection of the signal to determine the pulse rate of the transmitter. A slow pulse indicated the nestling was still alive. I visited the nesting area at various times of the day, but most visits occurred at dusk or during the first 3 hrs after dark. During dusk watches, I tried to determine if the instrumented owl could be detected during food deliveries by the parents, by its food-begging calls, or by observing it flying after it had reached fledging age. During every second or third visit, I used the radio signal to approach the owl on foot for visual confirmation of survival.

RESULTS

Only 3 breeding short-eared owl pairs were found during Study 3 benchland surveys (Lehman et al., this volume), despite intensive search efforts involving at least 700 hrs of observation at 11 occupied nesting areas. On 16 April, a short-eared owl was seen chasing a common raven (*Corvus corvax*) at the Kuna Cave nesting area. On 9 May, an incubating adult was flushed off a nest during a rope drag of the nesting area. A single egg was found in a simple scrape in the soil. However, no evidence of the nest or adult short-eared owls was found on 14 May and 25 May.

I found a second nest at the Range 14 North nesting area inside the OTA. On 8 May, an adult short-eared owl was seen chasing 2 northern harriers (*Circus cyaneus*) at this nesting area. Aggressive interactions between these birds and other raptors were also observed on 13 May and 27 May. The nest was located on 28 May, but no young were found in the nest scrape. One dead owlet was found approximately 3 m from the nest scrape. It appeared to have died several days before it was found, and was approximately 15 days old when it died. The cause of death could not be determined.

I found another young owl alive under a big sagebrush (*Artemisia tridentata*) about 5 m from the nest scrape. I banded this 13-day-old, 190-g owl with USFWS band number 816-74631 on its left leg, and placed a radio transmitter (frequency

= 166.743 MHz) on its right leg. The owl's weight agrees with published values for this age class (Holt et al. 1992). The area around the nest out to 30 m was searched unsuccessfully for other siblings.

I monitored the radio-tagged short-eared owl 22 times at 1- to 4-day intervals. I located the owl at 40, 210, 300, and 200 m from the nest at 18, 27, 32, and 37 days of age. On 20 July, I could no longer detect the radio signal. On 21 July and 23 July, I searched for the owl by vehicle without success. The area between Cloverdale Road and Mountain Home Air Force Base was searched with an omni-directional antenna while driving. I also scanned with a 3-element Yagi antenna from the tops of Bigfoot Butte, Christmas Mountain, and Cindercone Butte. On 26 July, I searched the nesting area again for the missing owl by walking parallel transects spaced at 10-m intervals and centered over the nest. A radio signal was not detected nor were any short-eared owls observed. I assumed the disappearance of both the radio-tagged juvenile and adult short-eared owls from the nesting area was the result of normal post-breeding dispersal. Dispersal age for the juvenile was approximately 58 days.

I confirmed breeding at a third historical nesting area (ISA Transect 792), but was unable to determine nesting success. On 30 March, I flushed a pair of short-eared owls from the ground in this nesting area, but no defensive behavior was observed. No owls were observed during 3 visits in May, but on 3 June I found eggshell fragments on the ground. I did not find a nest. On 22 July, an adult short-eared owl was seen chasing an unidentified raptor near the nest found on 3 June. During a search of the area on foot, I flushed a second adult owl, but no fledglings were found.

During dusk watches, I occasionally heard food begging calls from the instrumented owl at the Range 14 North nesting area, but I was usually too far away to locate the bird by its calls. I maintained observation distances of 200-300 m to avoid disturbing the adult owls during crepuscular feeding periods. Most prey deliveries apparently occurred after dark, so I was unable to locate the owl during feedings.

DISCUSSION

Because only 1 live nestling short-eared owl was found during the study, and it survived to dispersal, I was unable to assess survival of short-eared owls between the mid-nestling phase and independence. Radio tagging appeared to have no detrimental effect on the development of the young short-eared owl. However, the small sample size prevents any conclusions on radio effects.

Short-eared owl nests were much more difficult to locate then anticipated. I observed no aggressive behavior by nesting short-eared owls towards human observers during the study. No courtship displays were seen at any time. However, in 1992, courtship flights were observed at 2 nesting areas and defensive behavior was observed at 8 nesting areas (R. Lehman, National Biological Survey , pers. commun.).

In 1992, 24 occupied nesting areas were found in the SRBOPA, and breeding was confirmed at 12 nesting areas (R. Lehman, National Biological Survey, pers. commun.) The causes of reduced breeding by short-eared owls in the SRBOPA in 1993 are unknown. Lower numbers may reflect a cyclic population decline, or emigration of short-eared owls from the SRBOPA. Some short-eared owl populations, especially those dependent on voles (*Microtus* spp.), are synchronized with prey cycles (e.g., Korpimäki 1984). Other populations are nomadic and move between areas with irruptive prey increases (Clark 1975).

During this study, short-eared owls were commonly seen along the side of the road after dark. This suggests that short-eared owls did not emigrate to other areas in 1993. However, I could not determine if these birds were nonbreeders, if they attempted to breed but failed early, or if they were successful breeders whose nests were not found. It would be interesting to know if these owls were attached to nesting areas or were floaters. Yearly monitoring of short-eared owls will be necessary to better understand the species' population dynamics in the SRBOPA.

PLANS FOR NEXT YEAR

In 1994, I will continue the radio telemetry study but will radio adults as well as nestlings. I am also considering a food habits study and a study of small mammal populations to assess relationships between food availability and reproductive success.

ACKNOWLEDGMENTS

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Exploitation of Carcasses and Nesting Behavior of Common Ravens in the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*We observed common ravens (**Corvus corax**) foraging on carcasses in the Snake River Birds of Prey Area (SRBOPA) to determine how and why groups assemble. Carcasses were discovered by singletons or small groups, but the number of ravens exploiting a carcass quickly grew to an average of 9. Groups were formed primarily by local enhancement; recruitment from roosts was rare. Ravens found carcasses by cuing on other ravens, and more importantly, by cuing on black-billed magpies (**Pica pica**) and golden eagles (**Aquila chrysaetos**). This supports a progression of scavengers at carcasses that is mediated by dominance; subordinate magpies arrive first followed by ravens, coyotes (**Canis latrans**) and eagles. Few juvenile or subordinate ravens were captured approaching carcasses. Captive ravens "yell" when hungry, but this was rarely observed among free-ranging birds. Raven familial bonds are not evident for more than 1-2 months after fledging. Most ravens renested after their initial clutches were removed and did not abandon reduced or fostered broods. Two breeding females were observed copulating with more than 1 male.*

OBJECTIVES

1. Determine if ravens search for food singly or in groups and determine the importance of other scavengers and predators in alerting ravens to the location of a carcass.
2. Determine the relative roles of local enhancement and recruitment from roosts in the attraction of ravens to carcasses.
3. Determine if carcass size influences the relative importance of local enhancement and recruitment from roosts.
4. Determine if discoverers of carcasses defend them.
5. Determine the ages of ravens foraging on carcasses.
6. Determine if siblings forage together.
7. Record the ontogeny of raven vocalizations.
8. Monitor breeding success and responses of wild ravens to clutch removal, brood reduction, and fostering of young between nests.

INTRODUCTION

We began to investigate the behavior of common ravens at carcasses in the SRBOPA in 1991. The principal questions of interest to us are how and why ravens find carcasses and assemble at them to feed. The theoretical importance of such questions has been discussed elsewhere (Marzluff and McKinley 1992). Here we broaden our results from 1991-92 with additional information collected in 1993. We also initiated a study to assess the responses of ravens to nest manipulations (clutch removal, brood reduction, and

brood transfer). Information on breeding productivity was also obtained during this effort. The purpose of nest manipulation was to provide information important to the conservation of endangered corvids.

METHODS

Field procedures remained as in earlier years (Marzluff and McKinley 1992). In addition to opportunistic observations of foraging ravens, we observed 7 carcasses (4 mule deer [*Odocoileus hemionus*] and 3 black-tailed jackrabbits [*Lepus californicus*]) for 135 hrs from 19 February to 9 March 1993. Snow cover was continuous during this period.

Banding and nest monitoring efforts were increased in conjunction with the study of responses to nest manipulations as part of a larger project on the restoration of the Hawaiian Crow (*Corvus hawaiiensis*) in cooperation with the USFWS, Peregrine Fund, and Zoological Society of San Diego. Field procedures for this portion of the study can be found in Marzluff (1993). In addition, manipulations and observations carried out in the SRBOPA are summarized in Appendixes A and B.

RESULTS AND DISCUSSION

Exploitation of Carcasses

Discovery and Buildup of Ravens at Carcasses.—Ravens were most commonly observed flying singly or in small groups (Fig. 1A). Observations of up to 70 ravens flying as a group were made, but most large groups represented birds entering or leaving communal roosts. However, occasionally groups of 30-50 were seen soaring and traveling during the middle of the day. Most carcasses were discovered by single ravens (Fig. 1B; discovering party size = 1.5, n = 26, SD = 0.71), but groups eventually assembled to share the carcass (Fig. 1C). On average, 9.2 ravens fed at each carcass (n = 47, SD = 9.7), but numbers ranged widely from 4 to 50. Carcass size seemed to have little effect on the eventual number of ravens exploiting food (the maximum numbers of ravens observed were 50 at a jackrabbit and 30 at a deer). Large carcasses actually seem less preferred than small ones; ravens never fed at 3 of the 4 deer presented in 1993.

In total, we have observed ravens at 47 carcasses and watched 27 (7 large: deer and sheep, 20 small: jackrabbits and raccoons [*Procyon lotor*]) intensively for 400 hrs to determine the timing of discovery and subsequent buildup of birds. Carcasses were quickly discovered (time to discover = 95.3 min after placement in the field, n = 47, SD = 121.7), but ravens often waited 1 or more days before feeding on them. Carcasses were fed upon on the day of discovery 11 times (all were jackrabbits). Feeding began 1-6 days after discovery on 8 occasions (5 jackrabbits, 3 deer, 1 sheep). In 1 of these cases feeding did not occur until 60 days after discovery (a sheep). Eight carcasses were never fed upon by ravens (2 jackrabbits were eaten by northern harriers (*Circus cyaneus*), 1 was eaten by a golden eagle, 2 jackrabbits were not eaten during 2 days of observation, and 3 deer were not eaten by ravens; 2 of these were fed upon briefly by magpies).

The buildup of ravens at carcasses differs between the SRBOPA and the forests of western Maine. Buildup is primarily by local enhancement in the SRBOPA, but attraction from distant nocturnal roosts is common in Maine. We observed the change in numbers of ravens within versus between days 78 times at 22 carcasses in the SRBOPA (Fig. 2). Nearly all the variation in numbers of birds feeding in the SRBOPA was due to a gradual accumulation of birds during the day (Fig. 2A; solid bars). Most changes overnight represented the failure of birds to return to a carcass from 1 day to the next (Fig. 2A; open bars to the left of the 0, or no change, bar). In 1 case the number of ravens feeding at a deer increased from 3 to 30 overnight suggesting that some recruitment from roosts may occur, but the usual pattern of buildup is for numbers to increase quickly to 5 or 6 after 1 bird begins to feed. This small group then feeds sporadically until the carcass is consumed. In contrast, raven groups at carcasses in the northern hardwood forest of Maine often increase by 11-40 birds overnight (Fig. 2B). This is accomplished by information exchange at roosts (Marzluff et al. in press).

Ravens cue in on other scavengers and predators to locate carcasses in the SRBOPA. The presence of black-billed magpies at a carcass appeared to facilitate feeding, but not discovery, by ravens (Fig. 3). The time before ravens fed at carcasses was greatly reduced if 2 or more magpies were already feeding. Ravens and magpies appear to cue in on foraging golden eagles and attempt to

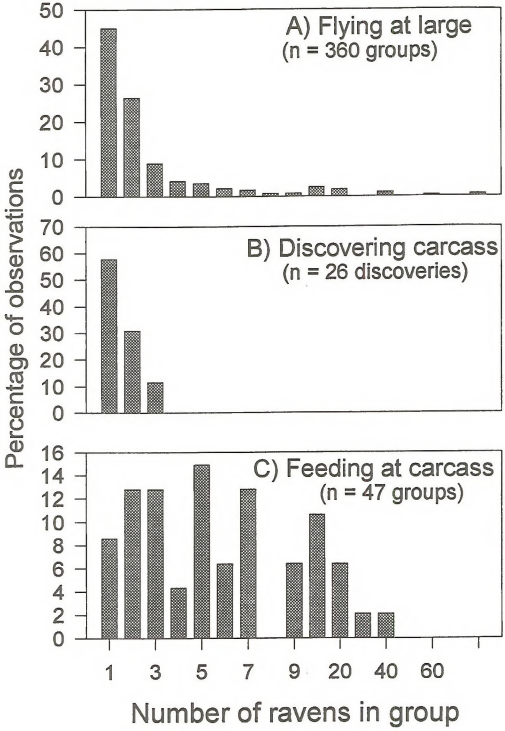

Fig. 1. Number of ravens in groups observed flying at large (A), discovering carcasses (B) and feeding at carcasses (C).

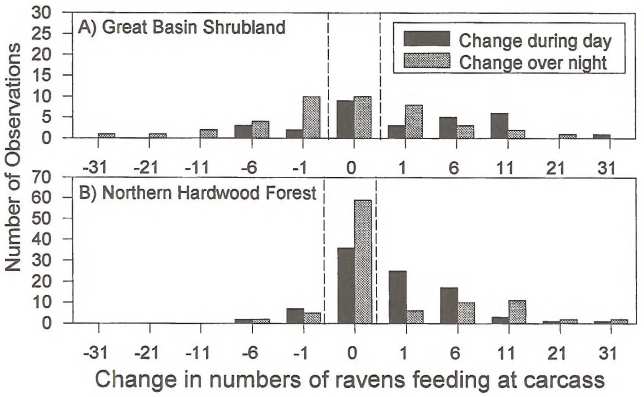

Fig. 2. The importance of local enhancement versus recruitment from the roost to the build-up of corvids at carcasses. Changes during the day equal the maximum number at the carcass during the day minus the number observed within the first 2 hours of the day. Changes over a night equal the number observed within the first 2 hours minus the maximum number observed the previous day. Zero indicates that numbers of corvids remained unchanged during the day or from 1 day to the next morning. Positive values indicate that numbers increased during the interval. Negative values indicate that numbers decreased.

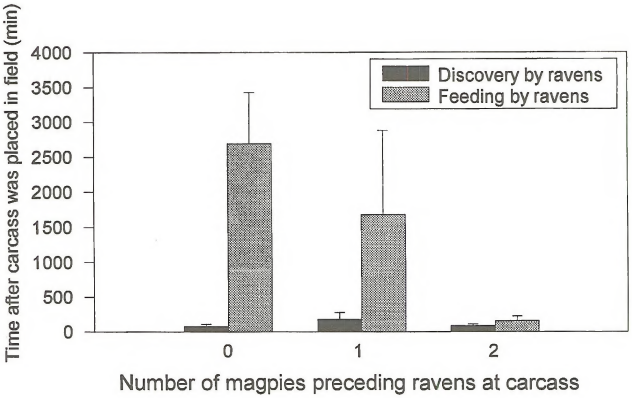

Fig. 3. Discovery of carcasses and feeding by ravens with respect to the number of magpies already feeding at the carcass. Averages plus 1 SE are plotted. Sample sizes for time to discover carcasses are 11, 3, and 11 for carcasses with 0, 1, or 2 magpies, respectively. Sample sizes for time to eat are 6, 2, and 11for 0, 1, or 2 magpies, respectively.

scavenge food from these predators after they make a kill. We observed magpies and ravens during 120 eagle forays. Both corvids showed significant numerical responses when eagles captured jackrabbits that were not evident when eagles captured smaller prey or were unsuccessful (Fig. 4). Half of all successful attacks on jackrabbits attracted ravens; one third attracted magpies (Fig. 4A). The average number of ravens increased from 0.95 to 5.4 after a successful attack on a jackrabbit and magpies increased from an average of 2.1 to 3.3 (Fig. 4B,C). The resulting number of corvids attending a successful kill was significantly higher than the number attending a successful kill of a smaller prey item (Townsend's ground squirrel [*Spermophilus townsendii*], rock dove [*Columba livia*], ducks, and reptiles) or an unsuccessful attempt (ravens: $F_{(2,117)} = 26.3$, $P < 0.001$; magpies: $F_{(2,117)} = 16.5$, $P < 0.001$). The increase in numbers of corvids after a successful kill was also significantly higher than the increase after a successful kill of a smaller prey item or an unsuccessful attempt (ravens: $F_{(2,117)} = 29.6$, $P < 0.001$; magpies: $F_{(2,117)} = 10.2$, $P < 0.001$).

Scavengers in the SRBOPA undergo a temporal succession at carcasses. We quantified this at 50 jackrabbit carcasses placed in the field to capture golden eagles in 1991-93. Observations at these carcasses prior to triggering of the traps indicated that magpies and occasionally coyotes discovered carcasses initially, often before sunrise (Fig. 5). Ravens were rarely seen at carcasses before 1 or 2 magpies had already accumulated. Numbers of ravens and magpies increased throughout the morning, peaking at approximately 1000 hrs. It is not surprising that magpies and coyotes were the first scavengers to discover carcasses because they rely upon smell in addition to vision to locate food (Buitron and Nuechterlein 1985). Ravens, and especially golden eagles, are more visually oriented and appear to find many carcasses by cuing in on magpies and coyotes. This temporal succession also may be organized by dominance at the carcass; our observations indicate that magpies are the least dominant member of the scavenging guild, followed by ravens, coyotes and eagles in increasing order of dominance.

Behavior of Corvids Foraging on Carcasses.—We increased our sample sizes of feeding and fighting rates at carcasses this winter. Trends observed last year continued; ravens fought more at carcasses as group size increased, and feeding rates did not decrease with increasing group size (Fig. 6). Therefore, although competition may increase at carcasses when many ravens are attracted this does not translate into a reduction in foraging efficiency per unit time. However, the overall length of time that a carcass would be available is reduced as more birds feed upon it.

Given the potential detriment of attracting others to carcasses, why do groups form? Group formation need not be beneficial to those already at a carcass (Sibly 1983, Marzluff and Heinrich 1991). If animals foraging at large are better off joining a group at a carcass than continuing their search, then they should join a group. This is likely the case in the SRBOPA because the short term costs of joining a foraging group appear low (Fig. 6), whereas the benefits of searching for other food may be low (other carcasses may be rare or defended by dominant raptors). Group foraging may have benefits as well; neophobia may be reduced, and the probability of securing prey from dominant raptors may be enhanced (Dixon 1938). This latter possibility is especially intriguing and will be investigated further.

Age of Ravens at Carcasses.—Seven ravens were captured while approaching jackrabbit carcasses. All of these birds had black mouths indicating that they were probably adults or exceptionally dominant immature birds (Heinrich and Marzluff 1992). Combining these captures with the 5 reported last year results in 9 black mouth birds and 3 pink mouth birds. Young birds appear to rarely forage on carcasses, a conclusion further supported by the lack of observations of tagged juveniles feeding on carcasses. This suggests that carcasses are exploited by a small subset of the SRBOPA raven population. Perhaps this subset represents a specialized segment of the adult population, or perhaps only dominants approach carcasses initially. Both possibilities may happen; dominants commonly are the first to approach carcasses (Heinrich and Marzluff 1991), but the lack of tagged juveniles at carcasses suggests that adults exploit carcasses more often than juveniles. Our observations of foraging by radio-tagged juveniles during the winter of 1993-94 will shed more light on this question.

Ontogeny of Vocal Development.—The development of vocal behavior was recorded in greater depth this year. Tape recordings of begging calls were made during captive-rearing, and "yells" were recorded when groups of captive-reared birds were housed together. Yelling was more fre-

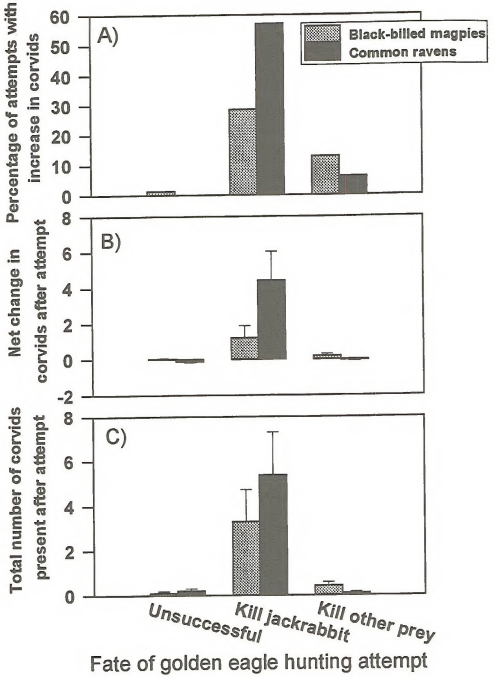

Fig. 4. Change in abundance of corvids after free-ranging golden eagles attempted to capture prey items. Three indices of change are presented: (A) the percentage of attempts that had an increase in corvids after the attack relative to before the attack, (B) the number of corvids after the attack minus the number before the attack, and (C) the total number of corvids present after the attack. Magpies were observed during 89 hunting forays and ravens were observed during 88 forays.

quent in these groups than among the 3 birds held last year. Yelling is common in response to a lack of food, as observed in Maine (Heinrich and Marzluff 1991). Yelling is rarely recorded when free-ranging birds forage at carcasses in the SRBOPA and has not been noted when birds feed on agricultural products or at dump sites. These observations suggest that ravens in the SRBOPA are rarely hungry.

Nesting Behavior and Manipulations

Association of Nestlings.—More detailed observations of radio-tagged juveniles this summer confirmed our previous observations that family bonds last for at most 2 months post-fledging. Juveniles join other ravens and forage widely across the SRBOPA during late July and August (see Marzluff 1993 for details of foraging ranges). Group membership at this time is not consistent.

Manipulation of Wild Pairs and Reintroductions.—We manipulated 8 pairs of ravens in the SRBOPA, primarily by removing their initial clutches, and reintroduced 18 free-flying ravens in the SRBOPA and adjoining lands (Appendix A, B). Adults typically responded to nest manipulations by renesting, but the success of renesting attempts was low. Captive propagation was successful and nearly 50% of the ravens reared in captivity and released are still alive. Results from this research are currently being used to steer recovery efforts for 1 of the rarest birds in the world, the Hawaiian crow. A detailed report of this research (Marzluff 1993) is available from The Peregrine Fund, Inc. (5666 West Flying Hawk Lane, Boise, ID 83709).

Parental Behavior During Egg Laying.—We observed 2 nests during the days immediately prior to egg laying, during egg laying, and after egg laying. Parental attendance and copulation frequency peaked when the first egg was layed (Marzluff 1993). Of greater interest were observations of copulation partners. Four different males (identified by fecal markings or patagial tags or

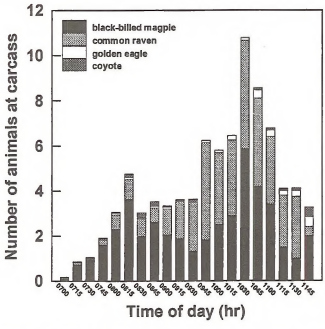

Fig. 5. Temporal succession of scavengers at jackrabbit carcasses. Carcasses were placed in the field to bait traps for golden eagles and observations were terminated when traps were sprung. Observations were made at a total of 30 carcasses, but the time that each carcass was observed varied so that sample sizes for each time interval range from 3 (latest time intervals) to 30 (earliest intervals). The number of animals per interval that is plotted is the average number observed during that time at all carcasses.

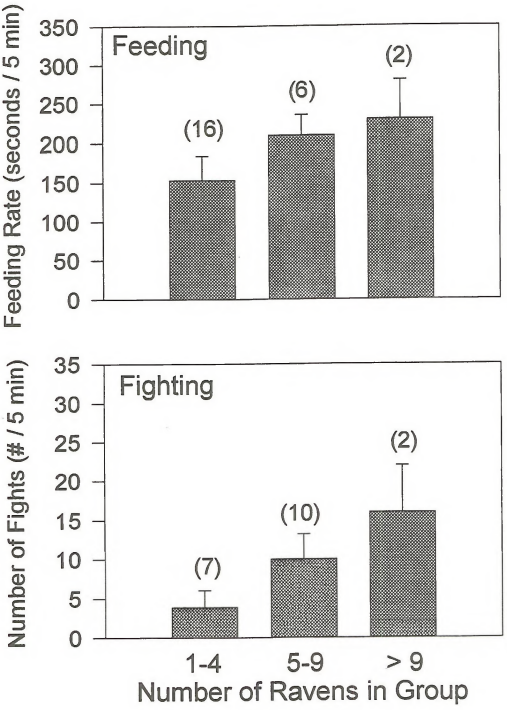

Fig. 6. The association between feeding group size and feeding and fighting rates. Feeding and fighting rates were calculated during 5 min focal samples. Averages plus 1 SE are plotted. Sample sizes are given above each bar.

leg bands) copulated with the female at the Initial Point nest, and 2 males copulated with the female at the Tadpole Butte East nest. The male paired with the female attempted to chase these interlopers off, but was rarely successful. The female appeared to act aggressively toward some males, but was neutral toward others.

PLANS FOR NEXT YEAR

We will continue to tag nestlings and monitor the exploitation of carcasses by corvids. We will increase our efforts to capture and tag territorial ravens and ravens discovering carcasses. The intriguing mutualistic information parasitism exhibited by raptors, corvids, and coyotes will be observed in greater detail in an effort to determine the costs and benefits to each participant. We will manipulate pairs and breed ravens in captivity as in 1993. This will also enable us to observe nesting behavior during egg laying and follow radio-tagged juveniles after they fledge.

ACKNOWLEDGMENTS

We would like to thank Sophie Osborn, Matt Dressler, and Dan Durland who spent hours watching dead animals do very little so that we might better understand how and why ravens form groups. Mark Pavelka, Beth Telford, and Kurt Stieglitz were indispensable in the manipulation and reintroduction work. We also thank Linda Schueck, Randy Townsend, and Mark Vekasy for keeping track of ravens while trapping for golden eagles. We appreciate the help of John Doremus and Lois Palmgren of the Bruneau Resource Area for biological and cultural clearance of release sites. Mike Kochert and Karen Steenhof helped in the permitting process, offered generous advice on the location of historical nesting areas, and provided literature and background information on ravens in the SRBOPA. This research was supported by Greenfalk Consultants.

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Appendix A. Productivity, tagging, and manipulation of common ravens in the SRBOPA, 1993.

Nesting Area	Nest Built/ Repaired	Pair Present in Territory	Clutch Size		Number of		# Patagial Tagged	# Radio Tagged	Manipulations*
			Initial	Renest	Eggs Hatched	Fledglings			
Tadpole Butte East	Yes	Yes	6	6	3	3	3	3	1,2,4 (2nd clutch was preyed upon, 3 nestlings were fostered successfully from Range 11Tower)
Range 15	Yes	Yes	1	0	0	0	0	0	None (nest removed by military)
Christmas Cinderpit	Yes	Yes	6	5	5	2	2	2	1,2,3
Bigfoot Butte	Yes	Yes	5	4	0	0	0	0	2 (renesting attempt abandoned due to military presence)
CSJ Jr.	Yes	Yes	5	-	@3	0	0	0	2 (nestlings from renesting attempt found dead at 3-4 days of age)
Cindercone Butte	Yes	Yes	7	0	0	0	0	0	2 (did not renest in area)
Initial Point	Yes	Yes	6	5	0	0	0	0	1,2 (renesting attempt preyed upon)
Thirst Draw	Yes	Yes	7	0	0	0	0	0	2 (did not renest in area)
Range 11 Tower	Yes	Yes	5	-	5	2	2	2	1,3 (3 nestlings moved to Tadpole Butte East)
Swan Road N. Side	Yes	Yes	6	-	6	@5	6	0	1
Peregrine Cliff	Yes	Yes	6	-	0	0	0	0	1 (preyed upon)
Fan Marker Range 10	Yes	Yes	5	-	0	0	0	0	None (nest blown down)
Cove Recreation	Yes	Yes	-	-	6	6	1	0	None
Balls Basin Powerline	Yes	Yes	6	-	5	0	0	0	1 (preyed upon)
Balls Basin	Yes	Yes	-	-	-	@3	1	0	None

Appendix A. (con't)

Nesting Area	Nest Built/ Repaired	Pair Present in Territory	Clutch Size		Number of		# Patagial Tagged	# Radio Tagged	Manipulations*
			Initial	Renest	Eggs Hatched	Fledglings			
Fawn Loaf	Yes	Yes	-	-	-	5	5	0	None
Wind Caves	Yes	Yes	6	-	-	3	3	0	None
Corder Creek South	Yes	Yes	-	-	-	4	4	0	None
APC Range 3	Yes	Yes	-	-	-	5	5	0	None
Grandview Feedlot	Yes	Yes	-	-	-	1	1	0	None
Bamman Split Rim	Yes	Yes	@1	-	0	0	0	0	None
Henderson Draw	No	No	0	-	0	0	0	0	None
Flagstaff Butte	No	No	0	-	0	0	0	0	None
Colt Draw	Yes	No	0	-	0	0	0	0	None
West Cabin	Yes	Yes	-	-	@1	-	0	0	None
Sun Goddess	No	No	0	-	0	0	0	0	None
Tadpole Lake	No	No	0	-	0	0	0	0	None
Little Joe Cave	Yes	Yes	0	-	0	0	0	0	None
Range 6	Yes	Yes	-	-	-	3	0	0	None
Higby Cave	No	No	0	-	0	0	0	0	None
Massacre Point	No	Yes	0	-	0	0	0	0	None
Powerline	No	No	0	-	0	0	0	0	None
Powerline Point	Yes	Yes	@5	-	@4	-	0	0	None

* 1 = visit every 3-4 days to measure growth rate
2 = remove 1st clutch for captive propagation
3 = reduce brood to 2 nestlings
4 = foster nestlings from other nest

Appendix B. Location, site statistics, and survivorship of common ravens released in the SRBOPA, 1993.

Release Site	In SRBOPA	Type of Site	Timing of Release	# at Site	# Surviving to Release	# Confirmed Surviving to 1 Dec 1993
Christmas Cinderpit	Yes	Aviary	Fledging	4	3	1
Range 11	Yes	Aviary	Fledging	2	2	0
Thirst Draw	Yes	Aviary	Fledging	2	2	0
Tadpole Butte East	Yes	Box	Fledging	4	3	1
Idaho State Prison A	No	Aviary	Fall	4	4	3
Grandview Feedlot	No	Aviary	Fall	2	2	1
Idaho State	No	Box	Fall	2	2	1

Habitat Relationships and Breeding Passerine Birds on the Snake River Birds of Prey Area

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ANNUAL SUMMARY

*We systematically surveyed breeding passerine abundances throughout the Snake River Birds of Prey Area using 200-m radius circular point counts. Breeding bird surveys were combined with vegetation surveys and landscape characteristics derived from analysis of satellite imagery to develop resource selection models for Brewer's (**Spizella breweri**) and sage (**Amphispiza belli**) sparrows, sage thrashers (**Oreoscoptes montanus**), horned larks (**Eremophila alpestris**), and western meadowlarks (**Sturnella neglecta**). Habitat selection by Brewer's and sage sparrows, and sage thrashers depended on both vegetation cover and landscape features. Horned larks and western meadowlarks depended on grassland cover or absence of shrubs. Our results have implications for fragmentation of shrubsteppe habitats.*

OBJECTIVE

To develop resource selection models for breeding passerine birds on the Snake River Birds of Prey Area.

INTRODUCTION

The effect of habitat fragmentation on biological diversity is an important consideration in the conservation of the earth's resources (Wilson 1988) because of detrimental effects on biodiversity and individual species distribution and abundance (Saunders et al. 1991). Predictions of effects of habitat fragmentation are analogous to theory derived from island biogeography. In habitat fragmentation, a large areal resource is reduced by disturbance or land use practice to a mosaic of smaller islands surrounded by inhospitable habitats. Patch size and interpatch distance (connectivity) are important components of the fragmented system (Urban and Shugart 1984). Species benefit or lose depending on dispersal and reproductive characteristics, degree of specialization, and dependence on the fragmented resource (Urban and Shugart 1984). Almost all studies of habitat fragmentation are from forested regions (Opdam 1991) or emphasize populations of rare species (Ehrlich and Murphy 1987, Shaffer and Samson 1987, Lamberson et al. 1992). Fragmentation of shrubsteppe habitats, although less studied than forest

fragmentation, is equally dynamic and no less significant (the trees are just smaller).

We tested the hypothesis that species distribution was independent of habitat and landscape characteristics. We integrated field censuses of birds and vegetation with landscape characteristics derived from Landsat thematic mapper satellite imagery to develop resource selection models (Manly et al. 1993) for 5 species of breeding passerine birds in shrubsteppe habitats: Brewer's sparrow, sage sparrow, sage thrasher, western meadowlark, and horned lark.

STUDY AREA

We conducted our study in approximately 260,000 ha of the Snake River Birds of Prey Area (116° E Long, 43° N Lat). Big sagebrush (*Artemisia tridentata*) communities dominate the region in the north and grade into salt shrub communities in the south (Yensen and Smith 1983). Large-scale fires between 1980 and 1989 converted approximately one-half of the shrub communities to grassland areas of cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola iberica*) (Kochert and Pellant 1986). Primary land-use activities are livestock grazing and military training (Kochert and Pellant 1986). Temperatures during hot, dry summers average 30-36 C during June-August; average amount of annual precipitation at the Swan Falls weather station is 26.9 cm, located within the study area.

METHODS

We sampled used and available habitats to develop resource selection models (Manly et al. 1993) for sage and Brewer's sparrows, sage thrashers, western meadowlarks, and horned larks. We sampled the entire study area for habitats and use at the population level, without identification of individuals (Sampling Design I, Protocol A; Manly et al. 1993). Assumptions implicit in any study to determine resource selection functions include stable distributions of measured variables and resource selection probabilities, correct identification of available and used populations, independent and random sampling, and that organisms have free and equal access to all resource units (Thomas et al. 1992).

Breeding Bird Surveys

The sample of used habitat units consisted of randomly located sites where a species was detected during breeding bird surveys. Census periods and number of sites were 30 Apr - 21 Jun 1991 (n = 75), 4 May - 25 Jun 1992 (n = 127), and 10 May - 23 June 1993 (n = 173). Sixty-nine sites were censused in all 3 years, 127 sites for 2 years, and 65 sites for 1 year. Sites were censused once during the season between 0600 - 1000 hr on mornings with little wind (<12 km/hr) and no rain. We recorded presence for unlimited-radius point counts of all birds seen or heard during a 5-min interval. One observer participated in all 3 years, 1 during 2 years, and 2 during 1 year of the censuses.

Habitat Surveys

Vegetation Surveys.—We sampled available habitat at 116 sites in 1991, 169 sites in 1992, and 103 sites in 1993. No major habitat disturbances, such as wildfires, altered habitats at points sampled during our study. Percent cover of plant species was determined by point frame technique (Floyd and Anderson 1982) within a 100 x 400 m area centered at the census point. We also grouped individual species into combined shrub and grass cover. Species richness (total number of species) and diversity (Hill 1973) were determined for each site.

Remote Sensing Data.—We used Landsat Thematic Mapper satellite images to describe landscape characteristics within a 1-km radius around each site. Image resolution was 25 m, and each survey site contained 5,023 pixels. Two images, taken on 9 September 1990 and 30 March 1991, were used to determine an abstract description of habitat. Each pixel had a value between 1 and 255 potential shades in each of 7 spectral bands (6 reflective, 1 thermal) in each image. Therefore, each pixel was described by 14 spectral variables.

We used principal components analysis (PCA) (PROC PRINCOMP, SAS Statistical Institute 1988) to reduce 14 spectral variables; the first component axis score was a habitat variable. To standardize variance among all sites, we scored pixels at each site using coefficients derived from a PCA of 10,000 random points within the study area. The first PCA component accounted for 64% of variation within the spectral data.

We determined the relationship between scores on PCA axis 1 and habitats by translating pixels into habitat classes using spectral data (Knick et al., this volume). PCA axis 1 represented a shrub-grass-disturbance gradient (Fig. 1) but was not related to cover of any single plant species (Knick et al. 1992).

We determined landscape heterogeneity from an omnidirectional variogram (Rossi et al. 1992) of the PCA Axis 1 values for each 25-m cell. The variogram calculates the semivariance, $\gamma(h)$, an estimate of spatial predictability, from the difference in value x for all possible point (z) combinations at a given distance:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [z(x_i) - z(x_i + h)]^2$$

where h is the distance between points, and N(h) is the number of pairs of points at distance h. We used 25-m increments in distance between point combinations because of the resolution of satellite imagery. Because points at distances >1/2 of the diameter sample only differences between edge locations (Rossi et al. 1992), we determined the semivariance for a 500-m radius around each survey site (or 1000-m maximum separation). We used a random subsample of 5% of the pixels (n = 251) within each site to generate 31,375 pair combinations. Number of pairs within each distance category ranged from 24 - 986 (30-50 are a recommended minimum; Rossi et al. 1992).

A log-log plot of γ as a function of h measured spatial predictability (Rossi et al. 1992). Sites with no spatial predictability between points (i.e., random values) have slope = 0 (Palmer 1988). Conversely, sites with high spatial predictability have slopes along the 45° identity line (Palmer 1988). Typically, the function follows the identity over short increments of distances between points but reaches an asymptote as more distant points become dissimilar (Fig. 2) (Phillips 1985). We used the semivariance slope to measure habitat heterogeneity. Average patch size for each site was determined by fitting a negative exponential function to the semivariogram and estimating the distance at 75% of the asymptote (Fig. 2).

Statistical Analyses

We used logistic regression to compare the sample of used sites with the available sample. We developed the resource selection model for each species with all years combined, with year included as a variable. When sites were surveyed in multiple years, we used the year when both vegetation and bird census data were collected.

All variables (Table 1) were initially entered in the logistic regression (PROC LOGISTIC, SAS Statistical Institute 1990) model in a backwards elimination procedure (Manly et al. 1993). At successive steps, the least significant variable was removed if it did not contribute to significant differences (-2 * maximum log likelihood χ^2 P < 0.05) in the model fit to the data until no variables remaining in the model met this criterion. We also determined standardized estimates for resource categories. Standardized estimates, the probability that a randomly selected resource unit will be in category i if all categories are equally abundant in the original population of available resource units (Thomas et al. 1992), permit comparison of relative selection among resource categories.

RESULTS

We detected Brewer's sparrows at 49 sites. Habitat selection by Brewer's sparrows was significantly related to shrub cover and shrub asymptote (Table 2). From standardized estimates of coefficients, shrub cover was almost twice as important as patch size (0.253 vs 0.145). Probability of occupancy was greater with increased shrub cover and patch size (Fig. 3).

Sage sparrows were present at 28 sites. Presence of sage sparrows depended on habitat heterogeneity, patch size, and sagebrush or shadscale cover (Table 3). For sage sparrows, the landscape features were more important (using standardized estimates) than cover values of individual shrub species. Probability of occupancy of sage sparrows increased with patch size and shrub cover (Fig. 4).

Sage thrashers were detected at 19 sites. Habitat heterogeneity (semivariance) and cover of sagebrush were significant variables in the resource selection model for sage thrashers (Table 4). As with Brewer's and sage sparrows, probability of occupancy increased with greater sagebrush cover and larger patch size (Fig. 5).

We detected horned larks at 117 sites and western meadowlarks at 115 sites. Resource selection by

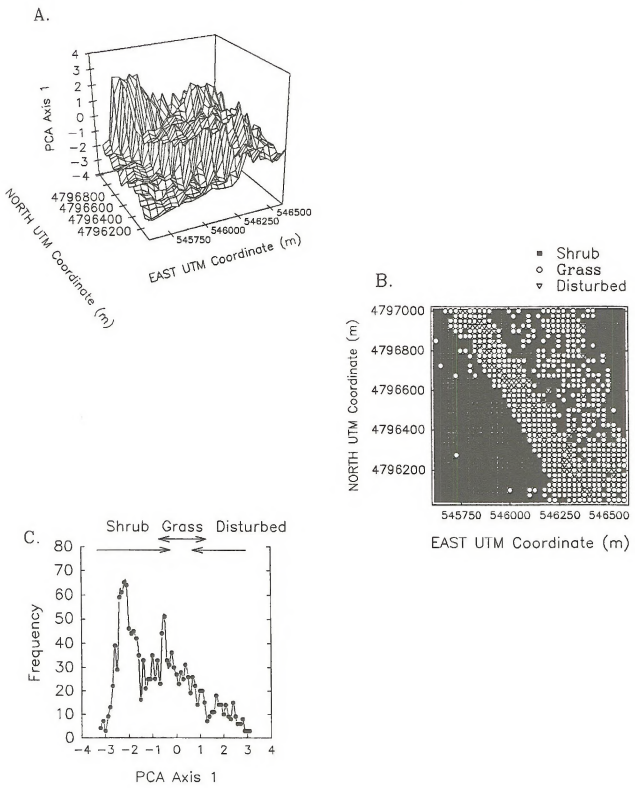

Fig. 1. Scored PCA axis 1 values (A), habitat type from translated satellite image (B), and distribution of PCA axis 1 scores with habitat associations (C) for site ISA284.

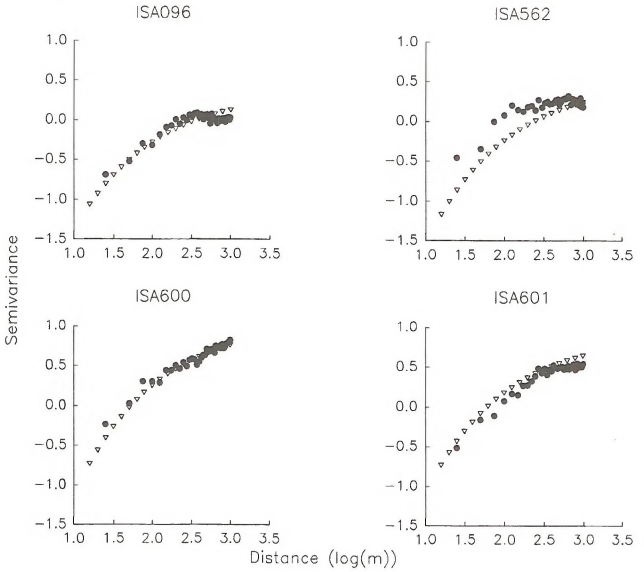

Fig. 2. Semivariograms for 4 sites surveyed in the Snake River Birds of Prey Area. Semivariance values (circles) for each distance are illustrated with the fitted negative exponential curve (triangles).

Table 1. Habitat variables used in logistic regression to develop habitat selection models for breeding passerines in the Snake River Birds of Prey Area.

Variable	Description
Sagebrush	Percent cover (Arcsin Transformation)
Winterfat	Percent cover (Arcsin Transformation)
Shadscale	Percent cover (Arcsin Transformation)
Shrub cover	Combined sagebrush, winterfat, and shadscale
Disturbed	Russian thistle, cheatgrass (Arcsin Transformation)
Grass cover	Sandberg's bluegrass, Six-weeks fescue, Bottlebrush squirreltail (Arcsin Transformation)
H	Vegetation species diversity
S	Vegetation species richness
Semivariance	Habitat heterogeneity
Asymptote	Patch size
Shrub asymptote	Patch size of shrub habitats
Grass asymptote	Patch size of grass habitats

Table 2. Significant coefficients for a resource selection model fitted by logistic regression for Brewer's sparrows.

	Parameter		Wald		Standardized
Variable	Estimate	SE	Chi-Square	*P*	Estimate
INTERCPT	-2.7509	0.2363	135.5251	0.0001	
SHRUB	4.3242	1.3458	10.3238	0.0013	0.254
SHBASYM	0.0521	0.0249	4.3951	0.0360	0.145

Table 3. Significant coefficients for a resource selection model fitted by logistic regression for sage sparrows.

	Parameter		Wald		Standardized
Variable	Estimate	*SE*	Chi-Square	*P*	Estimate
INTERCPT	-6.2649	0.9933	39.7801	0.0001	
SEMIVAR	3.6630	1.3370	7.5065	0.0061	0.343
SHBASYM	0.4364	0.2160	4.0840	0.0433	0.343
SAGEBRUSH	4.4783	1.9040	5.5322	0.0187	0.243
SHADSCALE	10.6149	5.0896	4.3497	0.0370	0.162

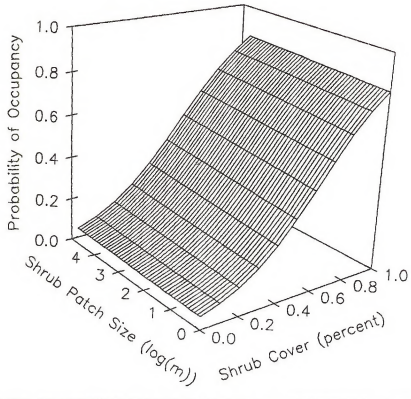

Fig. 3. Relationship between probability of occupancy and shrub cover and shrub patch size for Brewer's sparrows. Predicted values are fitted from logistic regression coefficients.

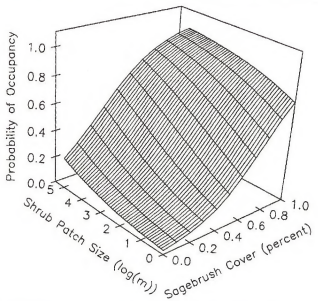

Fig. 4. Relationship between probability of occupancy and sagebrush cover and shrub patch size for sage sparrows. Predicted values are fitted from logistic regression coefficients.

horned larks was negatively related to sagebrush cover (Fig. 6), whereas western meadowlarks depended on the cover of grasses (Fig. 7). Horned larks and western meadowlarks did not select habitats based on landscape features (Table 5).

DISCUSSION

Both landscape and vegetation components influenced the presence of shrubsteppe species, Brewer's and sage sparrows, and sage thrashers. As a result, populations of these species may be impacted by continued fragmentation of shrubsteppe habitats by wildfire or man-caused disturbance. We do not know the mechanisms by which fragmentation influences these species. In forests, species influenced by fragmentation can have lower reproduction (Porneluzi et al. 1993) or incur higher rates of predation (Robinson 1992).

Population dynamics of species may be affected by similar mechanisms in shrubsteppe and forested regions. However, fragmentation of shrubsteppe may be less reversible and the impact on species more permanent because disturbed habitats tend to represent habitat sinks from which restoration is unlikely (Young and Evans 1978, Allen 1988).

PLANS FOR NEXT YEAR

We will repeat point counts with emphasis on sites surveyed in previous years. Because shrubsteppe birds in our study were influenced by

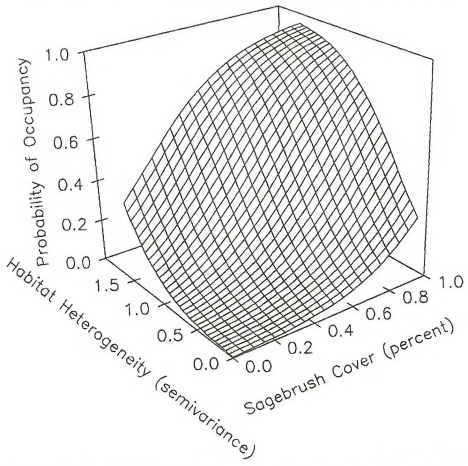

Fig. 5. Relationship between probability of occupancy and semivariance (habitat heterogeneity) and sagebrush cover for sage thrashers. Predicted values for each observation are fitted from logistic regression coefficients.

Table 4. Significant coefficients for a resource selection model fitted by logistic regression for sage thrashers.

Variable	Parameter Estimate	*SE*	Wald Chi-Square	*P*	Standardized Estimate
INTERCPT	-5.2060	0.9155	32.3329	0.0001	
SEMIVAR	3.0324	1.3383	5.1346	0.0235	0.284
SAGEBRUSH	4.6043	1.6987	7.3468	0.0067	0.247

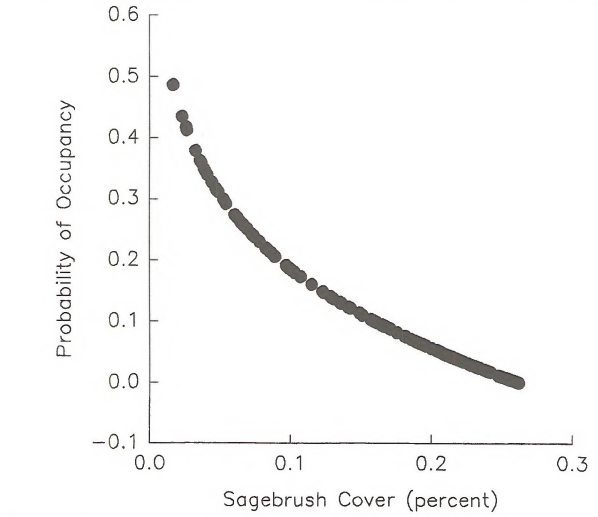

Fig. 6. Relationship between probability of occupancy and sagebrush cover for horned larks.

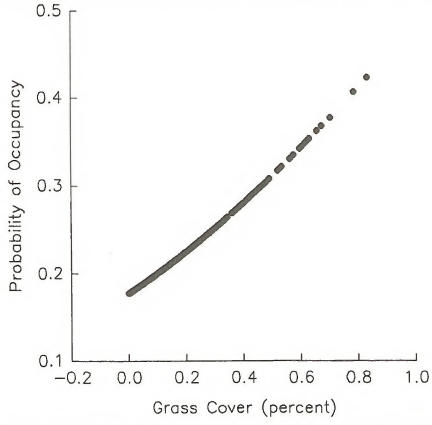

Fig. 7. Relationship between probability of occupancy and grass cover for western meadowlarks.

Table 5. Significant coefficients for a resource selection model fitted by logistic regression for horned larks and western meadowlarks.

Variable	Parameter Estimate	SE	Wald Chi-Square	*P*	Standardized Estimate
Horned Larks					
INTERCPT	-1.0355	0.1142	82.2621	0.0001	
SAGEBRUSH	-6.2420	2.0347	9.4108	0.0022	-0.295
Western Meadowlarks					
INTERCPT	-1.5337	0.1694	81.9464	0.0001	
GRASS	1.4695	0.6202	5.6140	0.0178	0.132

landscape characteristics, we will to identify sites in marginal habitats and attempt to determine mechanisms limiting the presence of birds. Depending on funding, we may determine if differential reproduction or predation influences nests located in marginal and optimal habitats.

ACKNOWLEDGMENTS

We thank Phil Bates, Dennis Johnson, and Kay Kessling for field assistance. Vegetation data was provided by the Bureau of Land Management Research Project, Study 5. Satellite images were provided by the Bureau of Land Management's Global Climate Change Program. Funding was provided by the U.S. Fish and Wildlife Service and the Bureau of Land Management. We appreciate administrative support from Mark Fuller, Mike Kochert, and Signe Sather-Blair.

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Colony Founding in Harvester Ants: Environmental Constraints and Population Implications

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ANNUAL SUMMARY

Our goal is to determine the importance of physical factors in determining the abundance and distribution of colonies of the harvester ant, ***Pogonomyrmex salinus****. Laboratory experiments were conducted to further explore the importance of dryness in determining survival and reproduction of queens. Several field studies were conducted: (i) densities of ant colonies on ca. 100 BLM transects were taken, and will be analyzed with respect to vegetation and mating site proximity; (ii) excavation of colonies was undertaken to determine the depths and temperatures at which eggs, larvae, and pupae are housed; (iii) colonies were shaded with cut shrubs or burlap to determine the response of colonies to decreased solar radiation; (iv) sagebrush seedlings were planted near colonies and the reaction of workers assessed; and (v) previously marked colonies were surveyed to determine if survival depends on proximity to shrubs.*

OBJECTIVES

1. To determine in the laboratory the temperature and moisture limits to reproductive success in newly-mated harvester ant queens.

2. To determine whether the factors that affect temperature and water potential (e.g., shrubs and slope) in the field can account for the distribution and abundance of harvester ant colonies, both on a microhabitat and a macrohabitat scale.

INTRODUCTION

Ants are a successful and ecologically important group. In desert areas of North America, harvester ants (genus *Pogonomyrmex*) are widespread and may have substantial effects on species composition and abundance in plant and animal communities, both natural and man-altered. Although their community ecology, behavior, and physiology are relatively well studied, little is known about what determines where and at what densities colonies of these ants are found.

The present research project is designed to identify the determinants of density and distribution of colonies of the harvester ant *Pogonomyrmex salinus* in southern Idaho. Every year each mature colony typically produces hundreds of winged queens, each of which may found a new colony. However, mature colonies may live for decades, indicating that very few new queens are able to found new colonies. It is reasonable, therefore, to expect that abundance and distribution of mature colonies will in large part depend on factors affecting success at founding new colonies.

In the present research we are focusing on 2 abiotic factors, soil temperature and water potential, both of which (i) should be of critical importance in determining the ability of a new queen to survive and produce brood, and thereby found a new colony, and (ii) vary substantially among sites in the field and therefore have the potential to play a major role in determining density and distribution.

METHODS

Laboratory

Previous lab studies showed that reproduction by queens strongly depends on temperature: they were successful only between 28 C and 36 C. There was also a suggestion of the importance of water potential. To further test this, newly mated queens were gathered from Initial Point in August and subjected to 5 temperatures (28, 30, 32, 34, and 36 C) and 8 water potentials (-62.5, -125, -250, -2000, -3000, -3500, -4000, and -5000 kPa) in a full factorial design experiment. Twenty-four queens were assigned to each of the 40 treatment types. Survival and reproductive success were assessed weekly until 15 December.

Field

1. Approximately 100 Study 5 transects in the SRBOPA (Knick, this volume) were visited. Each transect was first marked with surveyor's flags, then slowly walked, searching for ant colonies. Distance from the transect line to each colony found was measured. These data will later be converted to densities, using techniques described by Buckland et al. (1993). Also measured was the distance to the nearest mating site (this species uses rocky promontories). Data on the vegetation and soil characteristics of each transect were provided by Dr. Steven Knick. We will analyze these data using multiple regression, with density as the dependent variable, and vegetation, soil, and mating site measures as independent variables.

2. To determine the flexibility and thermal sensitivity of behavior within mature ant colonies, we excavated ca. 50 colonies during 2 dawn to dusk periods. Each excavation began with the digging of a hole ca. 40 cm deep next to the colony. The colony was then removed in vertical slices. Any time eggs, larvae, or pupae were found, the temperture of that chamber was immediately measured using a quick-registering thermocouple. Depth was also recorded. Temperatures at standard depths of 0, 2.5, 5, 10, 20, and 40 cm were taken.

3. To determine the effect of shading on mature colonies, we erected shades (consisting of pieces of recently-cut sagebrush or of burlap sacking) over ant colonies. Other colonies were unshaded. We visited each colony several times during the summer to assess activity and to determine if the colony had moved.

4. To determine whether colonies might take a proactive strategy in dealing with the nearby propogation of shade-producing sagebrush plants, we planted seedling sagebrush plants at 4 distances (0.5 to 2.5 m) from ant colonies. We then visited each colony several times and assessed damage inflicted by worker ants to the seedlings.

5. To determine if proximity of bushes might affect long-term survival and growth of ant colonies, we visited colonies marked 2 summers ago. We will analyze distance to shrubs vs. survival using regression analysis.

RESULTS

Laboratory

The data will be analyzed during the spring or summer of 1994.

Field

The data resulting from field studies will be analyzed during spring or summer of 1994. We can present the following initial results, however, based on a preliminary examination of the data.

1. Within colonies, workers are very sensitive to temperature. Brood are brought to chambers just below the surface as early in the morning as those chambers become warm. As the day progresses and the near-surface chambers become too warm, the brood are taken to deeper and deeper chambers. During the night, as the soil near the surface cools, the brood are taken to ca. 20-40 cm deep, where the temperature is relatively stable.

2. Mature colonies are sensitive to shading. Within hours of erecting shades, some colonies brought brood to the surface to warm them. Within days many of the colonies had commenced moving to new, unshaded locations.

3. Colonies wasted little time in defoliating seedlings planted near their colonies. Especially hard hit were those seedlings planted within 1 m of colonies.

DISCUSSION

The vast majority of data analysis remains to be completed. From the preliminary results presented above, however, it is clear that harvester ants are quite sensitive to the colony's temperature regime and that they take actions to affect the regime experienced by brood within the colony and by the colony itself.

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Producing a Burn Map for the Snake River Birds of Prey Area

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ANNUAL SUMMARY

This is the third year of long-term studies in the Bureau of Land Management's (BLM) global climate change research. In an attempt to develop a burn map for the Snake River Birds of Prey Area (SRBOPA) this year's efforts focused on using numerous standard change detection techniques on Landsat Multispectral Scanner (MSS) satellite imagery. We also attempted to digitize the fire boundaries from a CRT screen displaying the MSS satellite images. Each approach involved a comparison (digital and/or visual) of sequential MSS satellite imagery with the expectation that large changes between MSS scenes would be associated with recent burn scars. Both methods proved unsuccessful in delimiting an accurate map of areas that burned in the SRBOPA during 1987.

Although we originally proposed to develop a map detailing the annual fire history of SRBOPA (including the Orchard Training Area (OTA)) since the early 1970's, this goal seems unattainable using MSS satellite imagery. Burn scars in dense shrub habitats can be detected with some accuracy on a yearly basis, but burns in low density grass/exotic annual habitats continue to be difficult to identify. Further research will focus on change detection from shrub and/or natural grass to cheatgrass and/or exotic annual habitats over a longer period of time, versus a yearly time series.

OBJECTIVES

1. To determine the feasibility of correcting and updating the BLM annual burn maps for the SRBOPA.
2. To create annual fire maps in the OTA using MSS satellite imagery.

INTRODUCTION

Although annual BLM fire maps exist in most of the SRBOPA study area, 2 problems persist within the data. The fire boundaries were acquired by low-level flights without ground verification and/or correction, therefore errors ≥1.6 km exist in fire boundary locations. Second, there were no annual BLM fire maps produced in the OTA (Fig. 1).

In the previous 2 years of BLM's global climate change research, we collected data for historical weather and fire patterns in the SRBOPA and have attempted to map burns using MSS satellite imagery with unsupervised classification methods (Knick 1991, Kramber 1992). These methods were determined to be unacceptable in correcting annual BLM fire maps or creating annual OTA fire maps. This year's efforts focused on using MSS satellite imagery in change detection analysis with a further examination of screen digitizing methods.

METHODS

Study Area

The SRBOPA (116° E Long, 43° N Lat) includes approximately 195,325 ha of Great Basin desert rangeland in southwestern Idaho. Once predominantly shrubland, approximately one-half of the shrubland in the SRBOPA has burned since 1980 (Kochert and Pellant 1986). Burned shrublands now persist as exotic annual grasslands. Livestock grazing and military training are the primary land-use activities (Kochert and Pellant 1986).

Satellite Imagery

The 3 MSS satellite images used in the current analysis are the identical scenes used in the 1992 analysis (Table 1). These images were geometrically corrected using common ground control points and therefore were compatible for a temporal change detection analysis. A discussion of the rectification and geocorrection of these images can be found in Kramber 1992.

These MSS satellite images were chosen for their ability to bracket the summer burn season of 1987. It was thought that the spring 1987 scene (April 87) could serve as base data for the change detection analysis; the fall 1987 (September 87) scene would show the burns in the 1987 burn season; and the spring 1988 (May 88) scene would fully bracket the 1987 burn season.

Change Detection

We used change detection methods to detect areas that burned in summer 1987 by comparing September 87 and May 88 MSS satellite images with the April 87 image. We assumed that changes in ground characteristics caused by burns would be evident in the satellite imagery. We tested the effectiveness of each change detection technique by first performing the analyses and then overlaying the new coverage with boundaries of burns digitized from BLM burn maps for 1987. Effectiveness of the technique was tested by answering the question: could burns have been detected without the aid of the BLM burn maps?

Table 1. Landsat-5 MSS scenes used in the change detection analysis.

Path/Row	Date	Scene-ID
41/30	20 Apr 87	85114517490X0
41/30	27 Sep 87	85130517530X0
41/30	24 May 88	85154517562X0

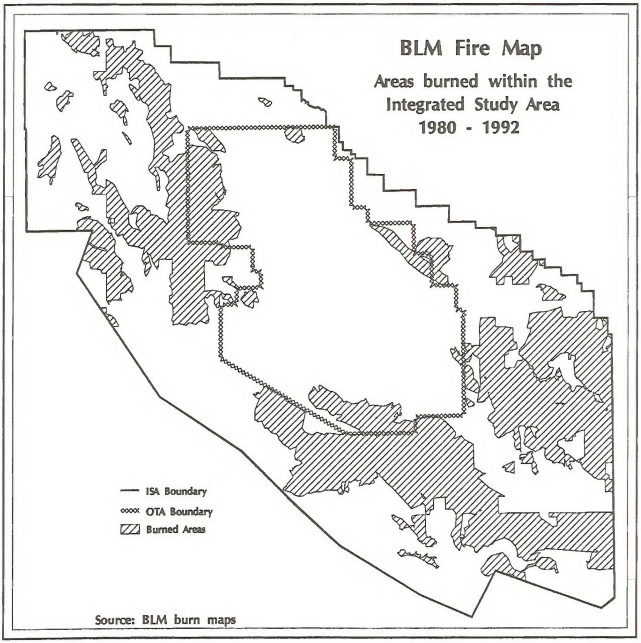

Fig. 1. Composite of annual BLM fire maps from 1980-1992. Absence of burned areas in the OTA reflects lack of mapping information for this area.

We used both transformed and untransformed spectral band data in the analyses as well as data corrected by a linear ratio and by radiometric rectification (Hall et al. 1991). Image transformation attempts to remove atmospheric, seasonal, or sensor differences between images by correction to a source image (Pilon et al. 1988, Price et al. 1992). Therefore, changes between images were more likely to result from vegetation differences rather than external sources. Our source image was the April 87 MSS image.

We made image corrections by developing a regression from the raw digital values of the second image to the corresponding band in the source image (Fung and LeDrew 1988). Common, or fixed, points in the images were selected, and the regression was developed from differences in band values. Band values in the second image were then corrected to the same scale as the source image.

Unlike linear ratios, radiometric rectification does not assume that differences are linear across the range of band values (Hall et al. 1991), but that the nonvegetated extremes in brightness/darkness are more critical than the fixed pixel approach. In radiometric rectification, the Kauth-Thomas greenness-brightness scattergram (Crist et al. 1986) was first developed for both images. Extremes in greenness-brightness regions in both images were then used to develop a radiometric transformation (Hall et al. 1991).

We used ratios of band values within images, such as the normalized difference ratio, perpendicular vegetation ratio, and the soil adjusted vegetation index (Huete 1988). Ratios attempt to reduce noise within individual bands and maximize combined characteristics (such as chlorophyll or water sensitivity) of individual bands (Richardson and Weigand 1977, Ustin et al. 1985, Walker et al. 1986).

We used a discriminant function analysis (PROC DISCRIM, SAS Statistical Institute 1988) to determine separation of classes for burned and unburned region. Image band values were predictor variables, and the class variable was burned/unburned. We also tested for differences in mean values of MSS bands between burned and unburned regions by Student's t tests (PROC TTEST, SAS Statistical Institute 1988).

A principal components analysis (i.pca, GRASS 4.0, U.S. Army Corps Engineers 1991) was used on all bands from 2 images (n = 8 bands) as a change detection technique to develop an ordination (Fung and LeDrew 1987). The first PCA axis is the linear vector that accounts for the greatest amount of variation in the data and should represent the sites that do not change between images. That is, high values in the both images will define the upper limit to the vector as sites with low values in both images define the lower limit. Subsequent vectors, at 90° rotations, represent sites that have changed between images. Axes 3 and 4 were most significant in detecting vegetation change (Milne 1986, Fung 1990).

RESULTS

All spectral variables within images were significantly different between burned and unburned regions (t tests, $P < 0.05$). However, the significance was due to large samples (burn 1986 n = 3,010; burn 1987 n = 3,597; unburned n = 6,775); the range of values for each spectral band overlapped substantially, and prohibited clear separation of burned/unburned classes.

Error rates for linear and quadratic discriminant function in classification of burned and unburned regions with untransformed spectral data ranged from 0.18-0.32. With image difference ratios and transformed spectral values as predictors, misclassification rate was 0.19-0.21 for linear functions, and 0.29-0.63 for quadratic functions. After radiometric rectification, misclassification rates were 0.21 for linear discriminant functions and 0.29-0.34 for quadratic discriminant functions.

The principal components analysis was also unsuccessful in identifying burns. Axes 1-6 were not significant in identification of burned areas after visual inspection of PCA scores with overlays of BLM burn maps. PCA axis scores demonstrated the least promise of any change detection technique.

DISCUSSION

Previous research has shown that desert regions are difficult to map with satellite imagery because of low vegetative cover and the resulting large influence of bare ground (Knick et al. 1992, Knick et al., this volume). Low vegetative cover translates to high soil reflectance which will dominate a pixel's reflectance value. Any low density

grass/exotic annual habitats disturbed by fire, overgrazing, vehicle tracking, or other large-scale disturbance will be difficult to detect, because most of the reflectance comes from soil. Also, these areas will most likely return to their previously existing habitat quickly. On the other hand, a dense shrub habitat disturbed by fire, overgrazing, vehicle tracking, or other large-scale disturbance will be replaced by grass/exotic annual habitat, and shrubs will begin to re-inhabit the area only after many years (Yensen 1982).

Change detection analysis was determined not to be a viable method for mapping burns in the SRBOPA, as has been demonstrated in other similar environments. Price et al. (1992) had ≈50% success with MSS imagery in detecting shrub die-off in the Great Basin region of the western United States. Richards and Milne (1983), and Milne (1986), reported limited success in detecting fire scars in Australia. Fung (1990), and Fung and LeDrew (1988) also had limited success with change detection techniques. We tried various change detection techniques in our attempt to produce an annual burn map for the 1987 fire season. We also met with limited success.

Both raw spectral data and the various transformations were less than successful in predicting burned regions. Inspection of change-images suggested that some areas with obvious fire scars were not detected (errors of omission), whereas other areas obviously not fire scarred (e.g., center pivots) were being highlighted (errors of commission). Unfortunately, because our independently derived burn data (BLM burn maps) were often in error (fire lines on map did not match apparent burn scars in an image), we were unable to create a reliable calibration function of spectral values to train an MSS satellite image as we did for vegetation mapping (e.g., Knick et al. 1992). Where change detection and screen digitizing seemed useful was in fine-tuning some of the boundaries of burns on the existing BLM fire maps; the MSS satellite imagery is poor at detecting burned areas not already identified (i.e., within the OTA, which lacks fire maps). Thus, creation of a historical annual burn map for the entire SRBOPA does not seem to be feasible. In the OTA, where fires have not been mapped and vehicle tracking or other large-scale disturbance has occurred, it may be impossible.

PLANS FOR NEXT YEAR

Because annual burn mapping using a series of MSS satellite images and standard change detection techniques does not seem feasible, our revised objective is to accurately define burn scars by using the 1979 vegetation map and/or 1979 MSS satellite imagery that brackets the time period of greatest wildfire incidence (1981-91). Although annual maps may not be possible, especially in low density grass/exotic annual habitats, we can better estimate fire boundaries and, hence, total area burned than from the BLM burn maps by using an approach that combines some screen digitizing and change detection over a longer period of time.

One of the 2 possible sources of base data for this analysis is a previously compiled vegetation map. In 1979, a vegetion map was produced for the SRBOPA (U.S. Dep. Inter. 1979). The 3-year project included the combined use of color aerial photography (scale 1:31,680) and some ground truthing. This vegetation map has habitat categories which can be combined into a general shrub and/or natural grass-cheatgrass/exotic annual habitat map of the SRBOPA.

Table 2. Landsat-3 MSS scenes to be used in the change detection analysis from 1981-1991.

Path/Row	Date	Scene-ID
44/30	12 May 79	LM83043317475X0
44/30	15 Sept 79	LM83055917463X0

The other source of base data would be a vegetation classification of 2 MSS scenes for 1979 (Table 2). This classification would use the same methods as outlined by Knick (1992) for TM satellite imagery. The training set for the supervised classification would be the ground truthed points done for the 1979 vegetation map. The supervised classification would be used to create a general shrub and/or natural grass-cheatgrass/exotic annual habitat map of the SRBOPA.

The 1979 vegetation map and the 1979 MSS vegetation classification will be used in a change detection analysis with the present SRBOPA vegetation map (Knick et al. 1992, Knick et al., this volume). The 2 vegetation maps, 1979 and the current SRBOPA vegetation map, will be digitally overlaid, and areas classified as shrub/natural grass habitat in 1979 and considered cheatgrass/exotic annual habitat in the current vegetation classification will generally be called burned/disturbed areas. This process would produce a aggregate map of burned/disturbed regions in the SRBOPA over the time period of greatest interest (1981-1991).

ACKNOWLEDGMENTS

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Monitoring Studies on Greenstrip Projects in the Snake River Birds of Prey National Conservation Area

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ANNUAL SUMMARY

Most greenstrip monitoring plots were visited, with data collected at 63 study sites on 13 greenstrip projects. Data will be evaluated to determine effects of a long-term drought on establishment and persistence of seeded, native, and introduced plants. Recruitment of a seeded, introduced shrub is almost 8 times higher than recruitment of a native shrub on a previously burned site.

OBJECTIVE

1. To monitor establishment and persistence of plants used to establish strips of fire resistant vegetation (i.e., greenstrips) in the Snake River Birds of Prey National Conservation Area (SRBOPNCA).

2. To document competitive interactions between an introduced and native shrubs.

METHODS

Most greenstrip projects are monitored with a procedure that combines cover, density, phenology, and frequency data collection. This procedure, called "Freqdens," is described in a previously published report (Pellant 1989). Prior to 1989, a pace transect was used to monitor several greenstrip projects (Pellant and Hall 1992). All studies include photographs.

RESULTS AND DISCUSSION

During the 1993 field season, 63 study sites on 13 of the 15 greenstrip projects in the SRBOPNCA were monitored. These data are being evaluated to assess the effects of an extended drought on greenstrip vegetation and adjacent plant communities. This information will assist managers in evaluating greenstrip project success over the last 8 years and plan future greenstrip projects.

Two study sites established in 1990 on an experimental greenstrip near Simco Road were resampled in 1993.

A site preparation and seeding machine (disk chain) was used to seed a crested wheatgrass (*Agropyron cristatum*) and forage kochia (*Kochia prostrata*) mixture after a 1986 wildfire.

Forage kochia is an introduced half-shrub that is very competitive with cheatgrass (*Bromus tecto-*

rum) and remains fire resistant throughout the summer. These studies document the competitive interactions between seeded and native species along 4 160-m transects. The transects originate at the greenstrip boundary and run into adjacent rangeland that was burned in the 1986 wildfire.

Number of mature forage kochia plants nearly doubled from 1992 to 1993, while mature shadscale (*Atriplex confertifolia*) plants, the dominant prefire shrub, decreased by 60% during this same period (Table 1). The number of 0.003-ha (0.01-acre) plots sampled was increased from 20 to 40 in 1993 to improve sampling accuracy. Therefore, a valid comparison of 1993 data with previous years data will not be appropriate until statistical tests are performed.

Forage kochia was better adapted to reproduce and establish seedlings in 1993 than shadscale. Relative recruitment of each shrub can be compared by dividing number of seedlings by the number of mature plants. Relative recruitment values of 0.12 seedlings per mature shadscale plant were 7.8 times less than the 1.54 seedlings per mature forage kochia plant. Forage kochia's recruitment advantage may be associated with a higher seed reserve in the soil or a better adaptation for germination and survival given the spring 1993 weather conditions. A relatively high mortality of forage kochia seedlings is expected.

Evaluation reports summarizing all greenstrip monitoring data are available at the Idaho State Office and at the Boise District's Bruneau Resource Area. These reports include site preparation and seeding descriptions, management actions, climatic information, and monitoring data.

PLANS FOR NEXT YEAR

Monitoring of selected greenstrip projects in SR-BOPNCA will continue in 1994.

ACKNOWLEDGMENTS

L. Williams and S. Klug assisted in the collection of 1993 monitoring data.

Table 1. Forage kochia and shadscale survival and recruitment (nos./ha) from 1990-93.

	Forage kochia		Shadscale	
	Seedling	Mature	Seedling	Mature
1990	0.0	4,544.8	24.7	1,951.3
1991	123.5	3,260.4	148.2	1,556.1
1992	444.6	4,297.8	86.5	1,901.9
1993*	11,610.9	7,529.1	149.8	1,186.2

* Number of plots sampled was doubled in 1993.

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Seedling Ecology of Shrubs Associated with Snake River Plain Wyoming Sagebrush Vegetation

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ANNUAL SUMMARY

*We sampled 8 sites which were typical of Wyoming big sage (**Artemisia tridentata wyomingensis**) and winterfat (**Ceratoides lanata**). Two Wyoming big sage sites and 2 winterfat sites were selected north of the Snake River, and likewise 2 of each were selected south of the river. The criteria for site selection were: (1) currently dominated by either Wyoming big sagebrush or winterfat; (2) representative of major soil types on which these species occur on the lower Snake River Plain; (3) minimal disturbance from livestock (enclosures were preferred), recreational, or agricultural use; (4) all season access from major roads; and (5) dispersal of sites to minimize potential loss of all sites from a single wildfire. Each sample plot consists of 4 parallel 100-m transects spaced 4 m apart. Initial sampling of each site was designed to characterize the site according to vegetation, soil surface and microsite.*

OBJECTIVES

1) Assess the major causes of first and second year mortality of seeds and seedlings.
   a. Determine the importance of seed caches versus single seed plantings in reproduction.
   b. Identify major causes of seed mortality.
2) Characterize microsites with "successful" seedling establishment.
   a. Locate and describe sites with successful natural regeneration. Sites will be described with respect to soil-surface, overstory, litter, plant composition and large herbivore-use characteristics.
   b. Place seeds into previously described microsites and follow individual plant history.
3) Determine the efficacy of soil modification to enhance natural generation.

SAMPLE PLOT SELECTION CRITERIA AND DESCRIPTION

We located 8 sample plot sites which were typical of Wyoming big sage sites (dominated by *Artemisia tridentata* ssp. *wyomingensis*) and winter-

fat sites (dominated by *Ceratoides lanata*). These sites will be used to conduct the more intensive safe site experiments of this project. Two Wyoming big sage sites and 2 winterfat sites were selected north of the Snake River, and 2 of each were selected south of the river. The criteria for site selection were: (1) currently dominated by either Wyoming big sagebrush or winterfat; (2) representative of major soil types on which these species occur on the lower Snake River Plain; (3) minimal disturbance from livestock (enclosures were preferred), recreational, or agricultural use; (4) all season access from major roads; and (5) dispersal of sites to minimize potential loss of all sites from a single wildfire.

Wyoming Big Sagebrush Sites

Sinker Creek. This site is located south of the Snake River on Highway 78, 1.6 km south of the Sinker Creek Crossing on the north side of highway just past the gravel pit (R1 W., T3 S., Section 28). There is some evidence of previous grazing in this area, but within the plot the generally thick and persistent cryptogamic crust indicates minimal disturbance. Species present include: *Artemisia tridentata* ssp. *wyomingensis*, *Artemisia spinescens*, *Ceratoides lanata* (trace), *Poa secunda*, *Sitanion hystrix*, and annual grasses and forbs.

Poison Creek. This site is located south of Snake River, 1.6 km south of Poison Creek (Mud Flat)/Castle Ck. Junction on Poison Creek Road (R2 E., T8 S., Section 24). This is 0.2 km southeast of the road in an existing exclosure that was constructed about 30 years ago. This is a dry, gravelly site with large open spaces and sparse cryptogamic crust formation. Species present include *Artemisia tridentata* ssp. *wyomingensis*, *Artemisia spinescens*, *Atriplex confertifolia*, *Tetradymia glomerata*, *Phlox viscida*, *Sphaeralcea*, *Lathyrus*, *Oryzopsis hymenoides*, *Sitanion hystrix*, and annual grasses and forbs.

Wildlife Viewing Area. This site is located north of Snake River, 24 km south of Kuna on Swan Falls Road and 400 m southwest of the road in the Snake River Birds of Prey Area (SRBOPA), (R1 W., T2 S., Section 24). There is some evidence of grazing in the vicinity, but cryptogamic crusts are thick and intact within the sample area. Species present include *Artemisia tridentata* ssp. *wyomingensis*, *Atriplex canescens*, *Tetradymia glabrata*, *Chrysothamnus viscidiflorus*, *Lathyrus*, *Eriogonum*, *Poa secunda*, *Sitanion hystrix*, and annual grasses and forbs.

Power Line. This site is located north of Snake River, south of Kuna on Swan Falls Road and east 400 m on the power line access road in the SRBOPA (R1 W., T1 S., Section 24). There is some evidence of grazing in the vicinity, but cryptogamic crusts are thick and intact within the sample area. Species present include *Artemisia tridentata* ssp. *wyomingensis*, *Ceratoides lanata* (trace), *Poa secunda*, *Sitanion hystrix*, and annual grasses and forbs.

Winterfat Sites

Sinker Creek. This site is located south of the Snake River on Highway 78, 1.6 km south of Sinker Creek Crossing on north side of highway just past the gravel pit (R1 W., T3 S., Section 28). Some evidence of previous cattle grazing occurs, but the site is relatively undisturbed in appearance. Species present include *Ceratoides lanata*, *Atriplex confertifolia*, *Artemisia spinescens*, *Artemisia tridentata*, *Phlox aculeata*, *Poa secunda*, *Sitanion hystrix*, *Oryzopsis hymenoides*, *Eriogonum*, and annual forbs and grasses.

Castle Creek. This site is south of the Snake River, 19.2 km north of Poison Creek (Mud Flat)/Castle Creek Junction on Castle Creek Road. The site is 0.2 km southeast of the road (R1 E, T5 S;., Section 22). The site is sandy, with evidence of erosion probably due to hilly topography and sandy soil. There is some evidence of past grazing, but the cryptogamic crust is present. Species present include *Ceratoides lanata*, *Atriplex nuttalii*, *Artemisia spinescens*, *Tetradymia spinescens*, *Phlox viscida*, *Poa secunda*, *Oryzopsis hymenoides*, *Eriogonum*, *Sphaeralcea*, and annual forbs and grasses.

Wildlife Viewing Area. This site is north of Snake River 24 km south of Kuna on Swan Falls Road and 400 m southwest of the road in the SRBOPA (R1 W., T2 S., Section 1). Sand and gravel, some disturbance due to rodents, and cryptogamic crust are present. Species present include *Ceratoides lanata*, *Atriplex canescens*, *Artemisia spinescens*, *Chrysothamnus viscidiflorus*, *Poa secunda*, *Oryzopsis hymenoides*, *Sitanion hystrix*, *Lathyrus*, and annual forbs and grasses.

Initial Point. This site is in the SRBOPA north of the Snake River, 1.6 km south of the Wildlife Viewing Area site and 0.2 km west of highway down a dirt road (R1 E., T2 S., Section 7). It is a sandy site with a stable surface except for rodent disturbance. Species present include *Ceratoides lanata, Artemisia tridentata* ssp. *wyomingensis, Poa secunda, Oryzopsis hymenoides, Sitanion hystrix,* and annual forbs and grasses.

PLOT SAMPLING PROCEDURE

The method of Echert et al. (J. Range Manage. 39:409-414, 1986) was modified and used to characterize the microsites. We also characterized the amount of naturally occurring regeneration of Wyoming big sagebrush and winterfat by counting seedlings within 1-m diameter circular plots.

At 1-m intervals on each transect the following microsite descriptions were made for the area within a 25-cm diameter circular plot:

(1) soil surface categorization categories were litter, bare soil, gravel, cryptogamic crust, bunchgrass, shrub, and disturbance (e.g., rodent burrows, ant hills).

(2) microtopography categorization categories were shrub coppice, coppice bench, intercoppice microplain, playette, and bunchgrass coppice.

(3) shrub adjacency: each 25-cm plot was measured with respect to distance to nearest shrub, compass direction of nearest shrub, and height of nearest shrub.

At alternate 1-m intervals, 1 m diameter circular plots were analyzed to determine percent vegetal cover for individual shrub species, individual perennial grass species, perennial forbs, annual forbs, annual grasses, and cryptogamic crust. In addition percent cover for each shrub species was measured along each 100-m transect using the line-intercept method.

At each 1-m interval, within a 1-m circular plot, natural regeneration was characterized:

(1) each seedling microsite (25-cm circular plot) was characterized according to soil surface categorization, microtopographic categorization, and shrub adjacency as described above.

(2) each seedling was mapped within the 1-m circular plot for future reference to seedling survival.

SEED COLLECTION AND ANALYSIS

Winterfat seeds were collected in late September from each of the the 4 winterfat sites. These seeds are currently being analyzed for viability and germinability. Wyoming big sagebrush seeds will be collected during late November.

PLANS FOR NEXT YEAR

Research during 1994 will consist of 2 phases. The first phase will consist of sampling and describing the types of microsites on which successful natural regeneration of sagebrush and winterfat has occurred. The sites sampled in 1993 will be re-sampled. Additional sites will be sampled which represent different successional stages of the 2 vegetation types. A total of at least 40 sites in the Wyoming big sagebrush and winterfat vegetation types will be sampled during the study.

The second phase will consist of artificially planting individual seeds or groups of seeds in the various types of microsites found in the 2 vegetations. The success of these planted seeds will be periodically re-sampled to establish the probability of successful establishment for the various microsites. Seeds collected from the local shrub population will be used to ensure ecotypic adaptation to the general site. This work will be conducted on the 8 sites sampled in 1993. Additional seed will be collected in 1994. This seed will be planted in 1995 to replicate the study under different climatological conditions.

Environmental Monitoring in the Idaho Army National Guard Orchard Training Area

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ANNUAL SUMMARY

*Two hundred eighty-one permanent land condition-trend vegetation/soil monitoring (LCTA) plots established in 1989-1991 were monitored, and burrow counts of Townsend's ground squirrels (**Spermophilus townsendii**, hereafter TGS) and badgers (**Taxidea taxus**) were monitored on the 60 traditional transects. We searched for and identified **Lepidium papilliferum** microsites north and east of Range Road/Orchard Road, and south of Orchard Road in the area between Range 6 and the northern boundary of the Orchard Training Area (hereafter OTA). During the spring, 50 photopoints were monitored in the north half of the impact area. Several previously unrecorded plant species were collected in the OTA and added to the herbarium, and 2 amphibian species were found in the OTA.*

OBJECTIVE

To assess and monitor the land condition and vertebrate populations in the Orchard Training Area in order to minimize the impacts of National Guard training.

METHODS

Vegetation/Soils Monitoring

Individuals of *Lepidium papilliferum*, a federally listed category 2 candidate plant species (hereafter called LEPA) were counted on the 4 traditional 1.6-km walking transects, monitored in early June; also in June, sagebrush (*Artemisia tridentata*) communities in the OTA were searched, and a rough count of LEPA plants was made.

Tagged LEPA plants marked in 1992 were counted monthly (except in snowy months) and their reproductive status noted, until November 1993, when all 1992-tagged plants were dead. In April 1993, 12 *Lepidium papilliferum* microsites were selected east of Range 6 for a demographic study. On 22 April, all LEPA plants in each of these 12 sites were marked with numbered aluminum tags. The tagged plants were counted monthly, and their reproductive status noted. During the monthly counts of tagged plants, numbers of untagged, "new" LEPA plants, were also recorded for each site. On 5 of the 12 sites, all untagged, "new" plants were tagged during each month's monitoring.

All LCTA plots were monitored in 1993. On all LCTA plots with shrubs, belt transects were

sampled in 1993. Shrub belt transects were monitored using the methods outlined in Quinney 1990. All shrubs were counted on 1990 transplant special-use plots, using the methods reported in Quinney 1990. On all plots, all slopes were remeasured (3 measurements for each plot) to standardize slope lengths to >5m and to conform more closely to the current Army method of LCTA slope measurement, which has changed since the plot establishment year (Tazik et al. 1991). A more detailed explanation of the LCTA methods used in the Orchard Training Area can be found in the U.S. Army Land Condition Trend Analysis (LCTA) Field Methods manual (U.S. Army Corps of Engineers 1987).

In April and May, the 50 photopoint locations in the north polygon formed by Range Road and the livestock drift fence were monitored, using the procedure outlined in the 1991 annual report (Quinney et al. 1991).

Vertebrate Monitoring

We did not trap small mammals this year.

In June and July, the 60 LCTA plots sampled in previous years were censused for Townsend's ground squirrel burrows and badger holes, using the method described in Quinney 1990.

In 1993, we did not monitor OTA reptiles. However, we did record the first amphibian species for the OTA.

RESULTS

Vegetation Monitoring

In 1993, the 281 LCTA plots were inventoried. On the 8 native shrub transplant plots established in 1990, all shrub seedlings were counted.

LCTA data collected are on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, the Boise District Bureau of Land Management, and at the Idaho Army National Guard Environmental Management Office, Gowen Field, Boise, Idaho.

Walking surveys were done in June to provide a rough estimate of 1993 LEPA numbers in the OTA; approximately 64,000 living individuals were counted.

Information collected on LEPA in 1993 is on file in Boise, Idaho, at the Army National Guard Environmental Management Office. LEPA demographic data have been sent to Dr. Susan Meyer of the U.S.D.A. Forest Service Intermountain Research Station Shrub Sciences Laboratory in Provo, Utah, where they are being compiled and analyzed.

Several plant species not previously recorded from the OTA were collected and identified (see Appendix A). Specimens collected were sent to Colorado State University for confirmation of species identifications and for herbarium mounting. Herbarium voucher specimens of the new plant species collected in 1993 will be archived in the herbarium of Colorado State University, Fort Collins, Colorado; duplicate specimens will be added to the Idaho Army National Guard herbarium. Of particular concern was the first-time appearance of rush skeletonweed, *Chondrilla juncea* L., in the OTA. Rush skeletonweed is a perennial composite of Eurasian origin, with a deep, tough root system (Whitson 1992). A little less than 1 ha of OTA *Chondrilla* infestation was found in 1993, and we uprooted all these plants the day we found them. However, many had already set seed. This noxious weed may infest larger areas of the OTA and nearby lands next year.

Vertebrate Monitoring

Traditional TGS and badger burrow-count transects were sampled during June and July 1993. TGS and badger burrow-count data are on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, and at the Idaho Army National Guard Environmental Management Office, Gowen Field, Boise, Idaho.

In 1993, we found 2 amphibian species in the OTA: the tiger salamander, *Ambystoma tigrinum*, and the Great Basin spadefoot toad, *Spea intermontana*. On 21 July 1993, we found several dozen salamander larvae in a temporary pond approximately 250 m east of Pleasant Valley Road, inside the OTA within a few meters of the OTA northern border. Two larvae were collected and grown out to maturity; we then identified them as *A. tigrinum*. Cattle watering trucks were

seen delivering water to this pond earlier in 1993, so the salamanders, which inhabit the irrigation canals several kilometers farther north (D.Q., pers. observ.), probably were carried into the OTA in cattle water trucks. It is not known whether the Boise area population of *A. tigrinum* is native or introduced, but the species is not found in most of the rest of the Great Basin (Stebbins 1985). Two adult *Spea intermontana* were seen on the same day in the same pond, but these were not collected. The salamanders probably did not survive in the OTA; the pond was dry by the end of August (D.Q., pers. observ.).

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Appendix A. Plant species collected in Orchard Training Area for the first time in 1993.

Amaranthus californicus (Moq.) Wats.
Antirrhinum orontium L.
Calochortus macrocarpus Dougl.
Chondrilla juncea L.
Conyza canadensis (L.) Cronq.
Draba verna L.
Eremocarpus setigerus (Hook.) Benth.
Langloisia setosissima (T. & G.)
Lappula echinata Gilib.
Lithophragma bulbifera Rydb.
Lithophragma parviflora (Hook.) Nutt.
Machaeranthera canescens (Pursh.) Gray
Microsteris gracilis (Hook.) Greene
Navarretia divaricata (Torr.) Greene
Phacelia lutea (H. & A.) J.T. Howell
Phlox muscoides Nutt.
Sonchus oleraceus L.
Verbena bracteata Lag. & Rodr.

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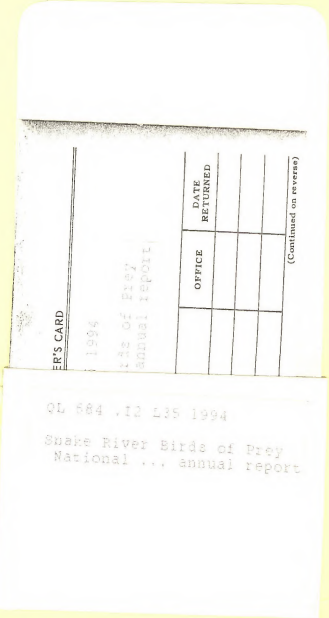

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